NEW MATRICULATION
PHYSICS

9

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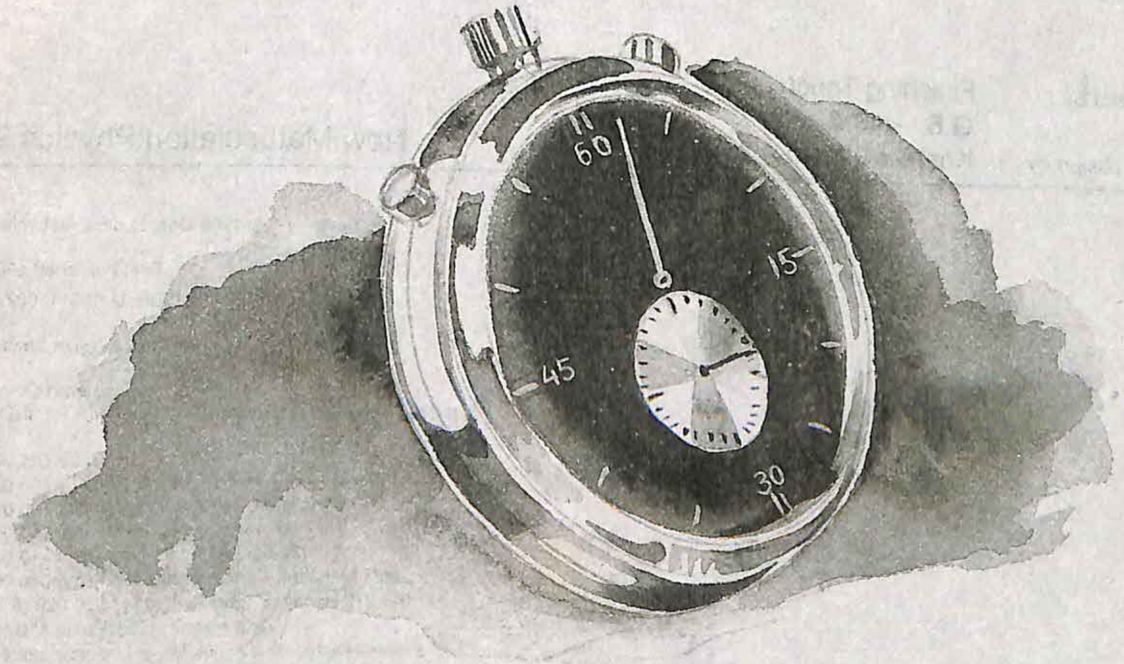

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To the teacher

New Matriculation Physics is a series of five books developed for class 6-10 of the Tamil Nadu Matriculation system. It closely follows the new enriched Matriculation syllabus.

One of the main features of the new syllabus is that activity and observation are given a very important place in understanding science. Every effort has been made to unfold the scope and purpose of the syllabus. This series departs from the conventional and emphasises a practical, 'discovery' and 'learning by doing' approach.

The subject matter to be studied has been carefully arranged keeping in mind the age level and psychology of the child. No effort has been spared to support the text with clear, labelled illustrations. The language has been kept simple and direct to enable the students to read the text themselves.

Several activities and projects have been suggested, wherever possible, within the scope of the lesson. Most of these need simple improvising or inexpensive materials.

The exercises for each chapter are exhaustive and include questions based on comprehension and application of basic principles rather than on mere recall.

It has been the concern of the authors that children are encouraged to discover for themselves the pleasure of learning about the fascinating 'laws of nature'.

The author

MATRICULATION SYLLABUS FOR STANDARD IX - PHYSICS

	Concept / Theme	*Expected outcome of learning*	*Teaching / Learning activities*
1.	**Measurement**		
1.1	System	Recognises the common system of ISI.	Finds out about ISI.
1.2	Units	Selects appropriate units in measuring.	
1.3	Length by vernier callipers and screw gauge	Realises the need to measure small lengths accurately.	Measures the length of small objects using a vernier callipers. Measures the diameter of thin wire or ball-bearing using a screw gauge.
1.4	Mass, using a physical balance	Estimates the degree of accuracy possible.	Measures the mass of an object accurately using a beam balance.
1.5	Time, using a stop watch or stop clock	Measures short intervals of time accurately.	Finds the time taken by a simple pendulum for 10 or 20 oscillations. Times a short race using a stop watch.
1.6	Density	Sees the relationship between mass, volume and density.	Finds the density of : — regular solids — irregular solids by the displacement method and weighing. — liquid using a r.d. bottle.
2.	**Mechanics**		
2.1	Forces acting on a body keeping it at rest. Principle of moments		Lists different types of forces acting on a body at rest. Verifies the laws of moments. Does simple numerical problems.
2.2	Meaning of motion	Recognises forces acting on a body.	Lists different types of motion.
2.3	Scalars and vectors	Differentiates between vectors and scalars.	Lists scalars and vectors.
2.4	Speed, velocity acceleration	Differentiates between speed and velocity.	Does simple numerical problems - calculating of resultant velocity.
2.5	Displacement / time and velocity / time graphs	Plots data with reference to velocity and time and draws graphs correctly.	Studies different types of d/t and v/t graphs and describes the motion of the object as seen from the graph.
2.6	Equations of motion	Analyses the derivation of these equations.	Does simple numerical problems.
2.7	Acceleration due to gravity	Modifies the equations of motion for bodies under gravity.	Does simple problems. Determines the value of 'g' in the laboratory using a simple pendulum.
2.8	Motion in a circle with uniform speed	Differentiates between linear and angular velocity.	Lists out bodies in linear and circular motion.
2.9	Newton's law	Analyses the meaning of inertia and force.	
	- First Law		Carries out simple experiments to show inertia.
	- Second Law	Analyses the meaning of momentum, and relation between force, mass and acceleration.	Simple numerical problems using gravitation and absolute units of force.
	- Third Law	Analyses the principle of action and reaction.	Lists examples to justify the law.
2.10	Streamlining	Recognises it as a way of minimising friction.	Observes, draws and lists objects moving through air and water which are streamlined.

	Concept / Theme	Expected outcome of learning	Teaching / Learning activities
3.	**Hydrostatics**		
3.1	Properties of liquids	Recognises liquid pressure.	Evaluates $P = hdg$.
3.2	Liquid pressure		
3.3	Atmospheric pressure	Relates the variables with reference to pressure.	Links weather changes to changes in air pressure.
3.4	Pressure in gases	Recognises the use of a manometer.	
3.5	Applications of fluid pressure - barometer - hydraulic press, jack, brake	Analyses Pascal's law.	Uses and reads atmospheric pressure using Fortin's barometer.
3.6	Archimedes' Principle	Recognises the buoyant force in fluids.	Experiments and observes density of solids and liquids using Archimedes' Principles.
3.7	Relative density.	Applies Archimedes' Principles in daily life situations.	Simple problems based on Archimedes' Principle.
4.	Heat		
4.1	Temperature and its measurement		
4.2	Thermometric scales		Learns conversion from C to F and vice versa.
4.3	Thermometers - Mercury, alcohol, clinical and max / min	Develops skill in the choice and use of suitable thermometers.	Reads the thermometer correctly.
4.4	Thermal expansion of solids, liquids and gases	Distinguishes between thermal expansion of solid, liquid and gases.	Conducts experiments and observes.
4.5	Heat energy and Gas Laws	Recognises the absolute scale of temperature.	Simple numerical examples.
4.6	Heat transfer - convection, conduction and radiation	Differentiates between conduction, convection and radiation.	Does experiments to appreciate the differences in the three modes. Heat insulation and ventilation as applications.
5.	Light		
5.1	Reflection - plane mirror	Analyses image formation in plane mirrors.	Lists characteristics of plane images.
	- spherical mirror	Relates experimental findings to geometrical facts in plane mirrors.	Lists characteristics of images, by drawing ray diagrams.
5.2	Mirror formulae	Analyses the mathematical relationship as applied to formation of images.	Simple coverage of sign convention, and formulae $r = 2f$ and $1/u + 1/v = 1/f$. Simple numerical problems on the relationship $1/u + 1/v = 1/f$.
5.3	Refraction - glass slab	Analyses the law of refraction.	Does experiments to verify the laws and effects of refraction.
	- prism, for deviation and dispersion	Differentiates between deviation and dispersion.	Does experiments.
5.4	Colours of spectrum	Distinguishes between primary and secondary colours.	Uses colour lights and filters to observe colour effects.
5.5	Lenses - image formation	Relates experimental findings to geometrical facts.	Lists image characteristics by drawing ray diagrams. Simple coverage of sign convention and object-image formula. Simple numerical problems on relationship. $1/u + 1/v = 1/f$ for a lens.
	- magnification and power	Estimates magnification, power.	Finds the magnification and power of a lens, by experiment and calculation.

	Concept / Theme	Expected outcome of learning	Teaching / Learning activities
6.	**Sound**		
6.1	Wave motion	Recognises the characteristics of wave motion.	Does experiments to see the differences between transverse and longitudinal wave forms.
6.2	Reflection - echoes	Recognises the applications of reflection of sound.	Use in SONAR and for determining velocity of sound in air.
6.3	Free and forced vibrations	Distinguishes between types of vibrations.	Lists examples of resonance and understands its application.
7.	**Magnetism**		
7.1	Magnetic field	Recognises uniform and non-uniform field patterns.	Maps magnetic lines force about a bar magnet, like and unlike poles, and north pole facing north or south in direction.
8.	**Light**		
8.1	Total internal reflection	Understands the cause of total internal reflection.	Explains the applications like mirage and atmospheric refraction of sunlight.
8.2	Total reflecting prisms	Recognises uses of prisms.	Observes their use in periscopes, binoculars.
8.3	Optical instruments	Recalls use of selected optical instruments.	Uses and observes their action.
	- Photographic camera - simple and compound microscope and telescope - human eye and its defects with their correction.	Sees relationship between part of camera and human eye. Recognises ways of correcting defective vision.	
8.4	Spectrum - infra-red and ultra-violet rays	Recalls the invisible parts of a spectrum.	Lists uses of these rays.
9.	**Magnetism**		
9.1	Earth's magnetism - dip and declination	Recalls dip and declination in the earth's magnetism.	Measures dip and declination.
10.	**Electricity**		
10.1	Electricity at rest - production	Recognises the rules of electricity.	Positive and negative charging produced by friction.
	- theory of electrification - electroscope - charge density	Analyses the theory of electrification.	Lists conductors and insulators. Charging by conduction and induction. Functioning of lightning conductors.
10.2	Electricity in motion - voltaic cell, dry cell and storage battery	Recognises the source of electric current.	Lists the advantages and disadvantages of each.
	- Ohm's Law, with cells in series and parallel - resistance in series and parallel involving two resistors	Sees the relationship between current and resistance.	Diagramatic representation of circuits. Does problems (numerical) based on two resitances in series and parallel.
	- Household circuiting	Adopts safety measures used in electrical supply.	Observes wiring, switches, fuses, plugs and earthing. Appreciates why electrical circuits in homes are parallel and not in series.

	Concept / Theme	Expected outcome of learning	Teaching / Learning activities
10.3	Atomic Physics - production of a stream of electrons by heat and by light	Reccognises the basis of electronics.	Makes a study of a hot cathode ray tube and its significance in the T.V. tube (simple, qualitative idea).
	- diode valve	Recognises uses of diode valve.	Makes a study of functioning of a diode and recognise its parts.

PRACTICALS

1. Measurement of length, area and volume using a vernier callipers.
2. Measurement of diameter of a thin wire or lead shots using a screw gauge.
3. Measurement of mass using a physical balance correct of a cg.
4. Determination of the value of g using a simple pendulum.
5. Determination of R.D. of liquid using a U-tube.
6. Verification of Archimedes' Principle.
7. Verification of the laws of reflection and refraction.
8. Determination of the value of a known resistance using a given circuit.
9. Plotting the magnetic fields around a bar magnet with N.P. towards north than south.

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1 Measurement

System - units - length by vernier calipers and screw gauge - mass, using a physical balance - time, using a stop watch or clock - density.

1.1 System

The application of the principles of science in our daily lives has produced the comfort and luxury of the world we now live in. As civilization developed and life became more complex, with man planting crops, trading goods, purchasing property, manufacturing goods, etc., it became essential for him to be assured of the quality of the goods he traded in or manufactured.

The Government of India has set up, by an Act of Parliament, the *Indian Standard Institution* so that the quality of goods sold or manufactured can be tested and certified.

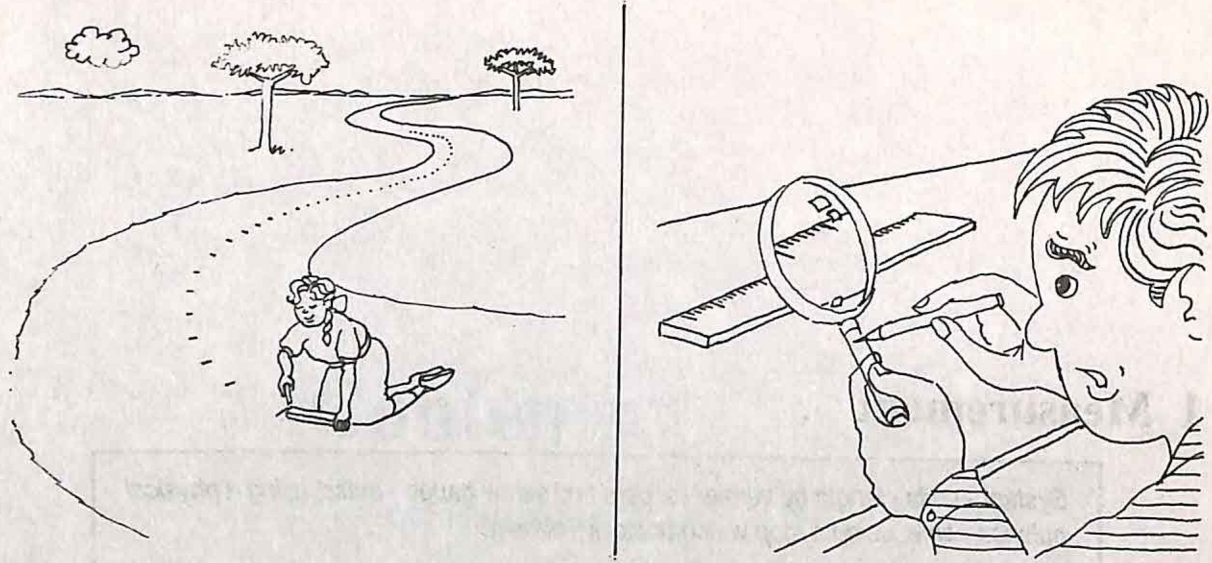
How can we know if the goods we are using are of a proper standard? The Indian Standard Institution provides a certification mark ISI on goods which shows that the Indian Standard Institute approves of the quality of those goods.

Activity 1 : *Make a list of articles in your home on which you find the ISI mark. Look on ink bottles, toilet articles, electrical goods such as mixers, grinders, heaters, etc.*

1.2 Units

All measurements in physics are related to the three basic quantities of length, mass and time. Until the 19th century various countries used different systems of units for measurements. Some used inches, while others used centimetres, etc. It was only in the latter half of the 20th century that a recommendation was made to use the metric system all over the world.

It is not always necessary to take exact measurements. For instance, if you want to know the length of a shoelace or ribbon it does not matter if the measurement is a few centimetres more or less than a metre. Again, if you are trying to measure your playground, it does not matter if it is a little more or less than a kilometre. It is possible for you to make a rough estimate in such a case. In fact, it is as important for one to have the ability to gauge correctly and quickly, certain lengths, weights, distances, etc. If someone were to ask you the distance from your school to the bus stop, you should be able to give an approximate answer without having to literally measure it.



a. Can you measure to the ten-thousandth of a cm accurately?

b. Can this be measured in cm, m or km ?

Fig.1.1

Activity 2 : *Try to make an intelligent guess at the measurements of the following:*

The length of your classroom .....
The width of your text-book .....
The thickness of a 10p coin .....
The length of your desk .....

To measure the thickness of the coin you could first measure 5 or 10 coins together. What would be the appropriate units in each case?

Now you can check whether your estimate is correct by using a ruler, or vernier callipers or a screw gauge. The instrument you use will depend upon

1. how accurately you want to measure something, and
2 . the size of the particular object. For more approximate measurements, a graduated scale is sufficient, but if you need to calculate the length to a fraction of a millimetre, you could use a vernier scale along with the main scale.

Activity 3 : *Try to make a guess at the following :*

1. The mass of your text book .....
2. The mass of your school bag .....
3. The mass of your pencil .....
4. The mass of a safety pin .....

Which units would you choose for each of the above ? Why?

We use various instruments to perform experiments. Some of the instruments are very simple and are used for simple experiments, e.g., a metre scale or a measuring cylinder. There are other instruments which measure dimensions with greater accuracy, e.g., vernier callipers, screw gauge, vernier microscope, etc.

Many of you would have watched the recording of the Olympic games on television. The 100 m, 200 m and 400 m events were particularly exciting. What was the difference in timing between the first and second place? Is this difference, in seconds or in a fraction of a second? Can you measure it with a stop clock or your wrist watch? Give reasons for your answer.

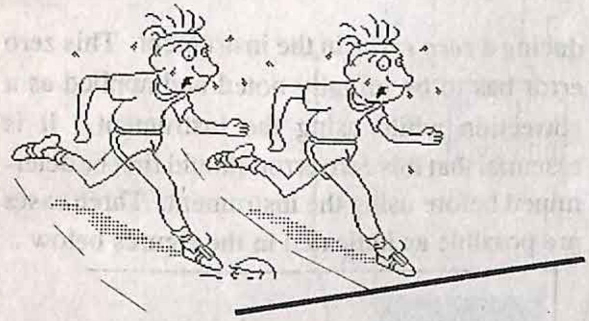


Fig. 1.2 The importance of timing accurately

In science too, when we measure very small quantities they need to be very accurate.

1.3 Measuring length using the vernier callipers and screw gauge

The vernier

Pierre Vernier, a French technician who lived in the seventeenth century, invented a supplementary scale, called the vernier scale. The vernier scale is used in conjunction with the main scale to accurately obtain the second decimal place of the centimetre or the inch.

The vernier in its simplest form consists of a small scale capable of sliding along the edge of the main or principal scale. The small scale is called the vernier scale, 10 divisions of which are equal to 9 divisions of the main scale (Fig.1.3).

In order to measure length with this arrangement, one has to determine the vernier constant or least count. The *least count* of any instrument is the smallest measurement that can be made by it. It is the difference between one main scale division (MSD) and one vernier scale division (VSD). From the above we note that

$$10 \text{ VSD} = 9 \text{ MSD}$$

$$1 \text{ VSD} = \frac{9}{10} \text{ MSD}$$

The value of one main scale division = 1 mm

$$\text{Therefore, } 1 \text{ VSD} = \frac{9}{10} \text{ mm}$$

$$\begin{aligned} \text{and the least count} &= 1 \text{ MSD} - 1 \text{ VSD} \\ &= 1 \text{ mm} - \frac{9}{10} \text{ mm} \\ &= \frac{1}{10} \text{ mm} \\ &= .1 \text{ mm} \\ &= .01 \text{ cm} \end{aligned}$$

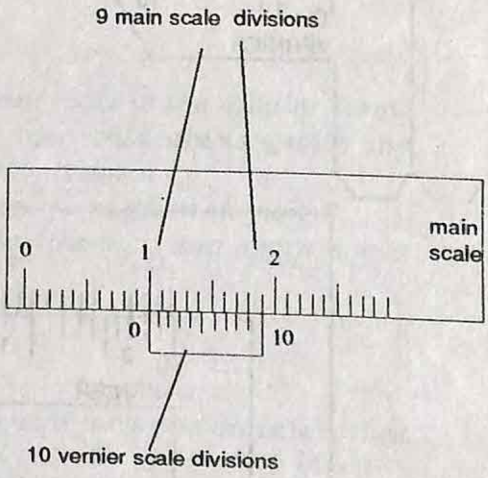
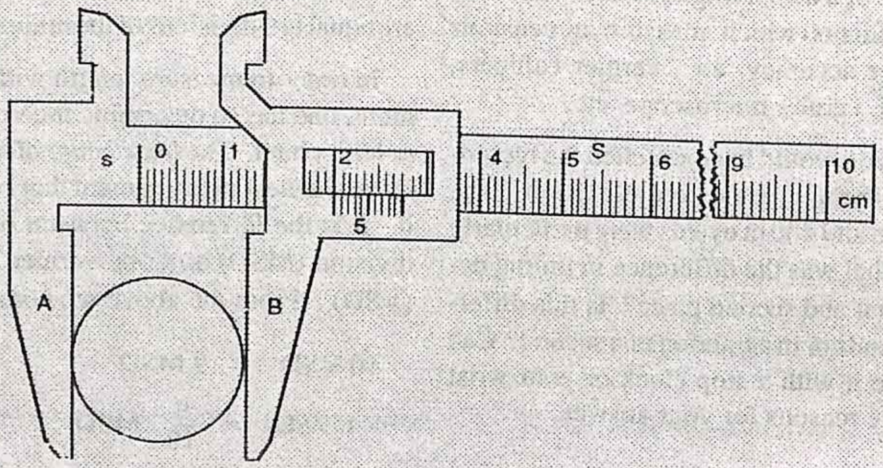


Fig. 1.3

Activity 4: *Given below is the diagram of a vernier. Label all the parts. Note the main scale reading and the vernier coincidence.*



ZERO ERROR

The vernier is so marked that when the two jaws are in contact with each other, the zero of the vernier coincides with the zero of the scale. But due to constant use of the instrument, the initial coincidence of the two zeros gets altered, introducing a *zero error* in the instrument. This zero error has to be initially noted and applied as a correction while using the instrument. It is essential that this zero error should first be determined before using the instrument. Three cases are possible as indicated in the figures below .

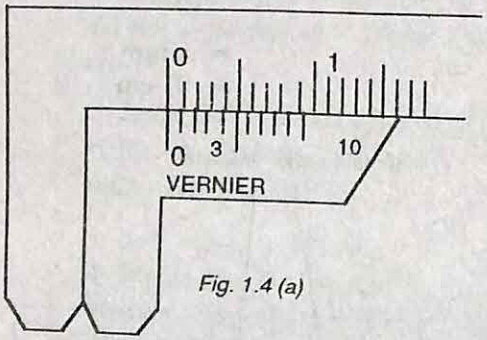


Fig. 1.4 (a)

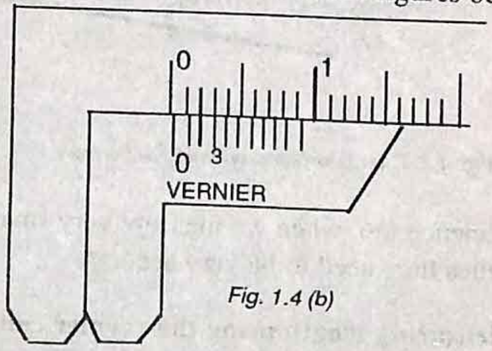


Fig. 1.4 (b)

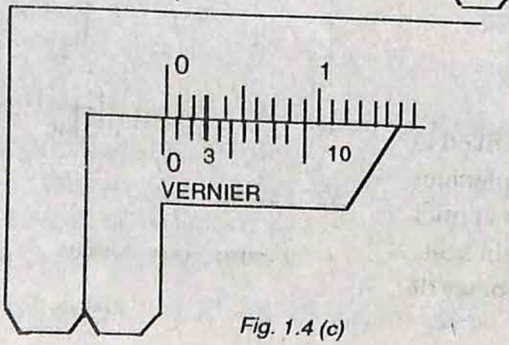


Fig. 1.4 (c)

Activity 5 : *Recall what you studied about zero error and zero correction in Class 8. Below each of the diagrams given in Fig. 1.4 note down the zero error and show how you would work out the zero corrections.*

Activity 6 : *Determine the length and diameter of a cylinder using a vernier callipers.*

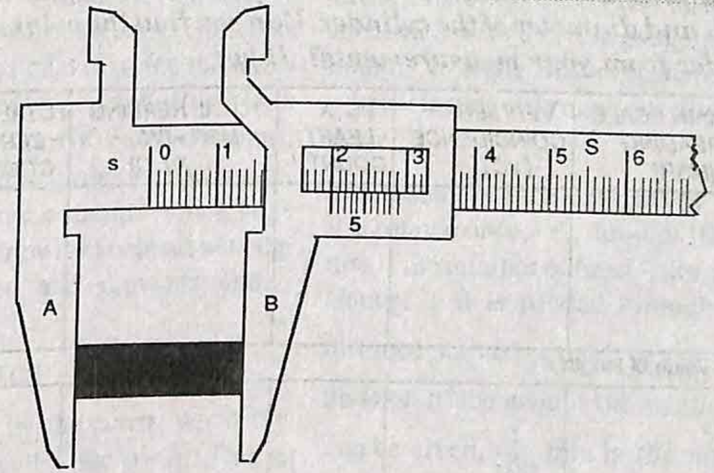
Things needed : *A vernier callipers, a small cylinder of brass or any other material.*

Method :

1. Find out whether there is any zero error in the instrument.

(a) Measuring length :

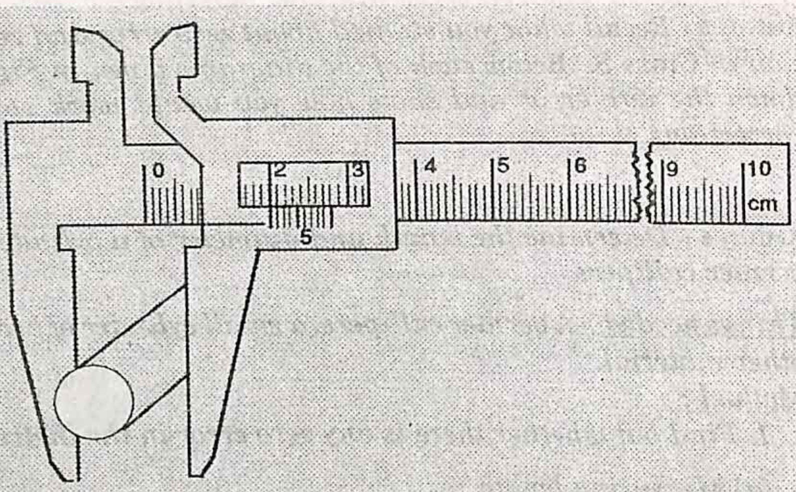
2. The cylinder is placed between the two jaws and held firmly lengthwise.



3. Note down the reading of the main scale in the tabular form.
4. Find out which division of the vernier scale coincides with any division of the main scale and note it down.
5. Complete the entries in the tabular form given in page 6.
6. Take the cylinder out from between the jaws and again repeat steps (2) to (5).
7. Repeat this five times.

(b) Measuring diameter :

8. Now take the cylinder from between the jaws and place it so that the curved sides are gripped between the jaws and take the readings again i.e., main scale reading and vernier coincidence.



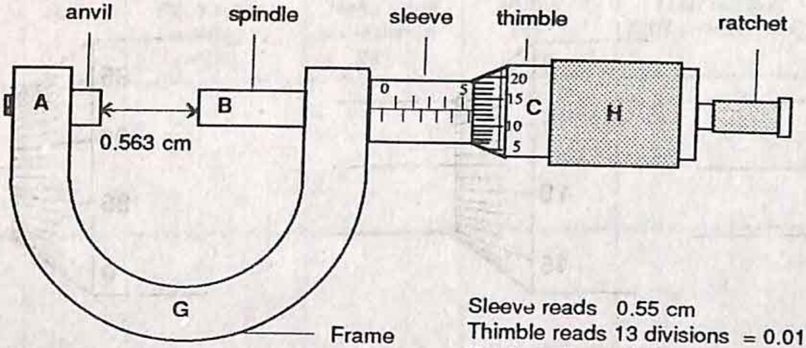
Write the values in the tabular form and repeat the above procedure by gripping the cylinder at different places. Find the average length and diameter of the cylinder. Can you find the volume of the cylinder from your measurements? How?

NO.	MAIN SCALE READING (MSR)	VERNIER COINCIDENCE (VC)	VC X LEAST COUNT	TOTAL READING MSR +(VC X L.C)	TOTAL READING ± ZERO CORRECTION (TR ±ZC)
1					
2					
3					
4					
5					
Mean value of length =					
1					
2					
3					
4					
5					
Mean value of diameter					

The screw gauge

The screw gauge is based on the principle of a screw which states that when a screw is rotated about its axis, it moves through a linear distance proportional to the amount of rotation given to the screw. This linear distance, through which the tip of the screw moves for one complete rotation of the screw, is equal to the distance between two consecutive threads of the screw.

Construction: The micrometer screw gauge consists of a U-shaped steel frame. One arm of this frame carries a stud called the anvil. The face of the anvil *A* is a plane. The other end of the arm is hollow and has a groove through which the screw *S* is moved by the head *H*. The end *B* of the screw *S* is also a plane. The screw moves inside a hollow cylinder called the sleeve, which has a linear scale in millimetres etched on it. This is known as the *pitch* scale. The horizontal line



Sleeve reads 0.55 cm
Thimble reads 13 divisions = 0.013 cm
Total reading = 0.563 cm

Fig. 1.5 A screw gauge

drawn on the main scale is called the *reference* or *axial line*. The head *H* carries a cap *C* called the *thimble*, to which the cylinder carrying the screw is related. The bevelled edge of the thimble is graduated into either 50 or 100 equal divisions. This is called the *circular scale* or *head scale*. Some screw gauges have a *ratchet* which slips when the end *B* of the screw is in contact with the object to be measured and prevents undue pressure on it.

PITCH

The distance travelled by the screw when the head is rotated once is called the *pitch*. This is determined by first making the zero of the head scale coincide with any division of the pitch scale. Now rotate the head through a specific number of rotations, say 5, and note the number of divisions moved on the pitch scale. The pitch is calculated using the following formula. If *n* is the number of rotations,

$$\text{Pitch} = \frac{\text{distance moved for } n \text{ rotations}}{n}$$

For instance, if the distance moved for 5 rotations is 5 mm then

$$\text{Pitch} = \frac{5\text{mm}}{5} = 1 \text{ mm}$$

Least Count : The smallest distance that can be measured with a screw gauge is called its *least count*. It is the distance moved by the screw when it is turned through one division of the head scale.

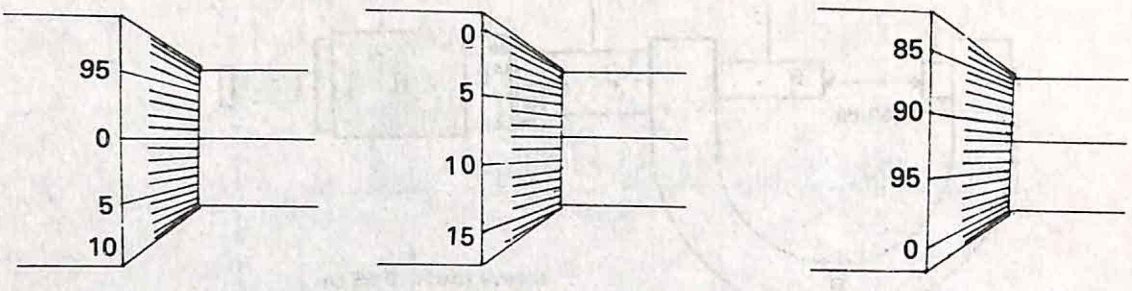
The linear distance travelled by the screw when it is rotated once, i.e., through 100 divisions, is 1 mm if the number of head scale divisions is 100. Hence, if it is rotated through 1 division, the distance moved would be $\frac{1}{100}$ mm. Since 1 division of the head is the smallest rotation that can be given, $\frac{1}{100}$ mm is the smallest distance that can be measured, i.e., the least count is $\frac{1}{100}$ mm.

$$\text{Least Count (L.C.)} = \frac{\text{pitch}}{\text{number of divisions on the head scale}}$$

$$= \frac{1}{100} \text{ mm} = 0.01 \text{ mm}$$

or .001 cm.

Zero error : If the zeros of the head scale and the pitch scale coincide when *A* and *B* are brought in contact with each other (Fig. 1.6), then there is no zero error and the readings taken will be correct.



a. no zero error b. positive error c. negative error

Fig. 1.6 Zero error

Zero correction : If the screw gauge has a zero error, correction has to be made to every reading taken with it. If the zero error is positive, the zero correction is negative, and if the zero error is negative, the zero correction is positive. The zero correction should be *added algebraically* to the reading.

Case 1 : If the zero of the head scale (Fig.1.6 b) is *below* the reference line of the pitch scale, say by 8 divisions, then the head scale would read 8 divisions instead of zero. This screw gauge has a *positive zero error* and any reading taken with such a screw gauge will read 8 divisions more than the actual reading. Hence 8 divisions have to be subtracted from the final reading.

Case 2 : If, however, the zero of the head scale is *above* the reference line, say by 8 divisions, (Fig. 1.6 c) then the head scale reads 92 divisions instead of zero. This screw gauge has a *negative zero error*. To correct this, count the number of divisions by which the zero of the head scale deviates from the reference line. This number multiplied by the least count gives the required zero error. Thus the zero errors in the above cases are + .08 mm and – .08 mm, (assuming the least count to be .01 mm) respectively. Therefore in *Case I* , .08 must be subtracted from the final reading and in *Case II* , .08 must be added to the final reading.

USING A SCREW GAUGE

Let us now learn how to use a screw gauge to measure the thickness of a glass plate or the diameter of a thin wire.

1. First find out the pitch of the screw and calculate its least count using the method already given.
2. Next find the zero error of the screw gauge and note down the zero correction.
3. Then rotate the screw backwards and insert the object in the space between the plane surfaces.
4. Rotate the thimble till the object is gently gripped between the two faces and the ratchet starts slipping.
5. Note the number of complete divisions on the pitch scale, and the division on the head scale coinciding with the reference line. Now you have the Pitch Scale Reading (PSR) and the Head Scale Coincidence (HSC).
6. Tabulate your readings as shown. The observed thickness (or diameter) is given by the formula

PSR + (HSC x LC)

and the corrected thickness (or diameter) =

PSR + (HSC x LC) ± ZC

The thickness should be calculated as follows: (LC = 0.01 mm ; zero error = + .08 mm ; zero correction = – .08 mm)

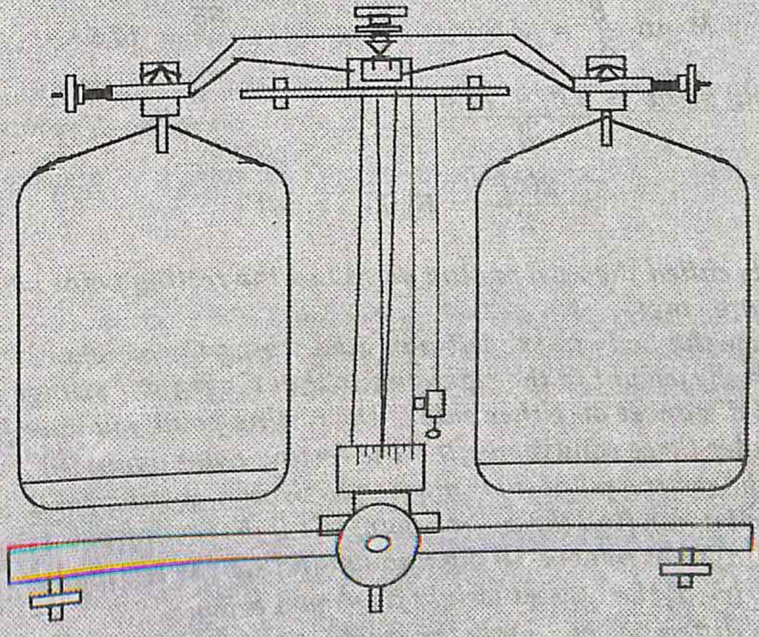
Object	S.No.	Pitch scale reading (PSR)	Head scale coincidence (HSC)	HSC x LC	Total reading PSR + (HSC x LC)	Total reading ± ZC
diameter of glass bead	1 2 3 4 5					
diameter of wire	1 2 3 4 5					

Average diameter of glass bead = ...
Average diameter of wire = ...

1.4 Measuring mass using a physical balance

You have already learnt about the construction and use of the physical balance last year. This year you will actually use the balance to determine the mass of an object.

Activity 7 : *Look at this figure of a balance. Try to label all the parts of the balance.*



Activity 8 : *Using the physical balance to find the weight of an object.*

Things needed : small object such as a glass stopper, or a small metal cube or cylinder, a weight box.

To use the balance :

1. Observe if the balance is level. If not, adjust it by working on the two screw feet till the plumb-line hangs centrally over the index.

2. Gently turn the handle to the right. If the beam does not oscillate, wave the hand over one of the pans to disturb the air and make it oscillate and observe if the pointer moves equal distances on either side of the central division.

3. We have to find out the division at which the pointer will finally rest. This takes time. We, therefore, find it by noting five consecutive turning points and then following the calculation indicated below:

Turning points

	Left	Right
	2	18
	3	17
	3	
Sum ...	8	35
Mean	$\frac{8}{3} = 2.6$	$\frac{35}{2} = 17.5$

Resting point $= \dfrac{2.6 + 17.5}{2}$

$$= \frac{20.1}{2} = 10.05 = (a)$$

This is called the zero resting point i.e., the resting point when the pans are empty.

4. Place the body in the left pan, and trying the weights in order, adjust the weight in the right pan so that the pointer swings nearly equal distances on either side of the resting point you have found.

5. Under these conditions find the resting point again (b).

6. If the resting point (b) is more than the zero resting point, add 10 mg and again find the resting point (c). If the resting point (b) is less than (a),then remove 10 mg and again find the resting point (c).

7. Arrive at the correct weight as shown below :

For a difference of 10 mg, the least weight in the box, we have two resting points (b) and (c) one on either side of the zero resting point (a).Of these, (b) and (c),find which is nearer to the zero resting point.

Record your observations in this tabular form .

Load in pans x 10^{-3} kg.		Turning points		Mean of the turning ponts		Resting point	Correct mass of body x 10^{-3} kg.
Left	Right	Left	Right	Left	Right		
Nil	Nil					Z.R.P. (a)	
Given body	W (weight)					(b)	
Given body	W ± 10mg.					(c)	

If (b) is nearer in value to (a) than (c), then the correct weight is the weight corresponding to (b), otherwise it is the weight corresponding to (c).

Activity 9: *Questions to think about:*

What is the unit of the weights in the weight box?

What is the unit of the fractional weights?

Did you use both in the above experiment?

How many decimal places are there in the mass of the body obtained in the above experiment?

To which part of a gram is the above mass correct?

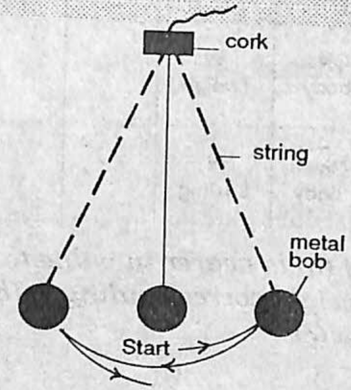
1.5 Time

Activity 10: *Make a list of all the timing devices you have read about or seen. Put the most accurate on top of the list and the least accurate at the bottom. What is the unit in which time is measured?*

Activity 11: *Using a wrist watch with a second hand find your friend's pulse rate ! A pulse rate is the number of heart beats in one second. Put your fingers on the wrist in line with the thumb. You can feel the pulse beating. Now start counting as soon as the second hand crosses the 12 mark on your watch and stop counting when it next crosses the same mark.*

Activity 12: *Set up a simple pendulum by tying a string to a metal bob and suspend it from a stand. Let the string be fairly long — about 60 or 70 cms. Now pull the bob aside and release it. It will start oscillating. One to-and-fro motion is one oscillation. Start your stop-clock when the bob just crosses the (centre) position of rest. Count the oscillations each time the bob passes the rest position in the same direction. When you reach 10, stop the stop-clock and note the time taken. Repeat this five times.*

S.No.	Time for 10 oscillations seconds
1	
2	
3	
4	
5	



Average time for 10 oscillations =
You can repeat this for 15 or 20 oscillations.

1.6 Density

Objects made of different substances, having the same mass, occupy different volumes. For example, if we take two cylinders of the same mass, one of lead and one of aluminium we will see that the volume of the aluminium is nearly four times the volume of the lead cylinder. Why?

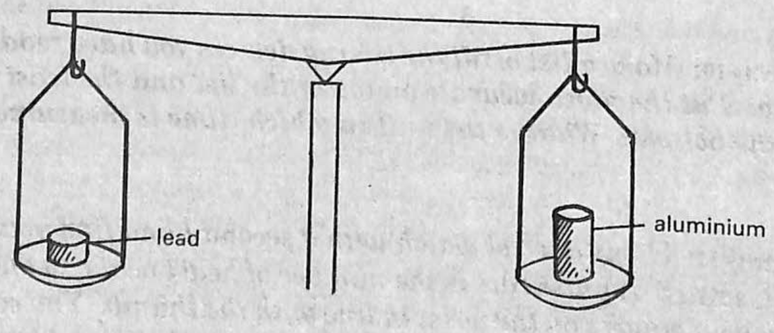


Fig. 1.7

Similarly, if you take 1 cm cubes of different materials, i.e., same volumes and weigh them, their masses will be different.

The mass of unit volume of a substance is called its density. Hence, from the figures below,

density of water = 1 gm per cc.
Mercury = 13.6 gm per cc.
Iron = 7.8 gm per cc, etc.

$$\text{Hence, density} = \frac{\text{mass}}{\text{volume}}$$

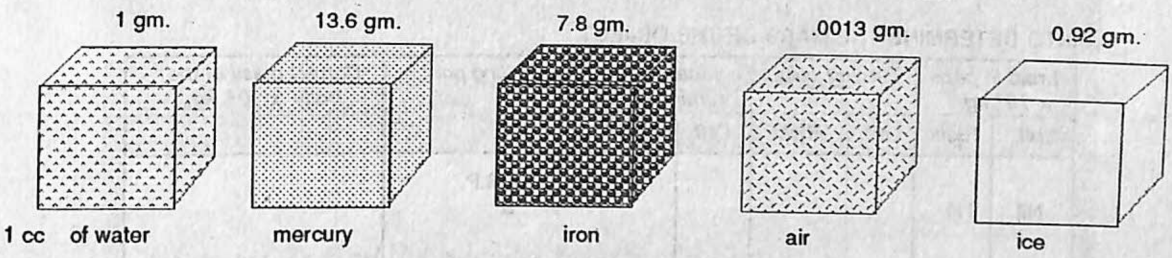


Fig 1.8 The density of various substances

If we use the symbols *d, m* and *v* for density, mass and volume respectively, we have

$$d = \frac{m}{v}$$

The unit of density in the SI system is

$$\frac{\text{kg (mass)}}{\text{m}^3\text{ (volume)}} \text{ or kg per m}^3 \text{ or kg m}^{-3}$$

To calculate mass from density we have

$$\text{mass} = \text{density} \times \text{volume}$$

$$\text{or } m = d \times v \text{ kg}$$

also, to calculate volume

$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

$$\text{or } v = \frac{m}{d} \text{ cu. m.}$$

Activity 13: *To find the density of a regular solid.*

Things needed: *Regular solids such as a cube, cuboid, sphere or cylinder, vernier callipers, a physical balance and a weight box.*

Method: *Choose any regular solid and measure its dimensions using a vernier callipers. For example, if the object is a cuboid you would measure the length, breadth and height using a vernier callipers. Record your observations in the tabular form. Then find the mass of the object using the physical balance. Record your observations as follows:*

I. TO DETERMINE THE VOLUME OF THE OBJECT

LEAST COUNT OF THE INSTRUMENT = ... ZERO ERROR = ...

Dimension	*S.N*	*Main Scale reading cm*	*Vernier coincidence div.*	*V.C x least count*	*Total reading MSR + (VC x L.C)*	*Total reading ± Zero correction (cm)*
length	1 2 3					
breadth	1 2 3					
thickness	1 2 3					

Mean length 'l' = ... cm .
Mean breadth 'b' = ... cm.
Mean height 'h' = ... cm
Calculation of volume: Volume of the cuboid $= l \times b \times h$ cu. cm
$= l \times b \times h \times 10^{-6}$ m^3

II.TO DETERMINE THE MASS OF THE OBJECT

Load in pans $\times 10^{-3}$ kg.		Turning points		Mean of the turning points		Resting point	Correct mass of the body $\times 10^{-3}$ kg.
Left	Right	Left	Right	Left	Right		
Nil	Nil					Z.R.P. =	
Given body							
Given body							

Corect mass of the body = ... *gm*

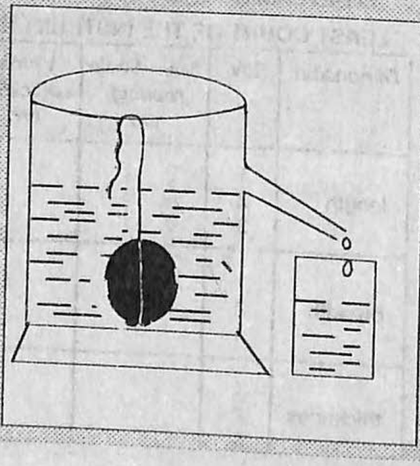
= ....*kg*

Calculation of density : Density $= \dfrac{\text{mass}}{\text{volume}} =$

Result : The density of the given object = ...

Activity 15: *To find the density of an irregular solid.*

Things needed: Overflow jar, measuring cylinder, irregular objects such as a glass stopper, physical balance and weights.



First find the volume of the solid using the overflow jar and measuring cylinder.

Let it be V cc.

Then weigh the solid in the physical balance. Record your observations. Let the mass of the solid be m gms.

Calculations:

mass of the solid $= m \times 10^{-3}\ kg$

volume of the solid $= v \times 10^{-6}\ m^3$

density of the solid $= \frac{m}{v}\ kg/m^3$

$$= \frac{m \times 10^{-3}}{v \times 10^{-6}}\ kg/m^3$$

Result: The density of the given solid is ____.

Activity 15: *To find the relative density of a liquid using a r.d. bottle.*

Take a clean, dry r.d. bottle and weigh it empty. Then fill it with the given liquid and find its weight. Pour out the liquid, rinse it well with water and fill it with water. Determine its weight accurately with a physical balance. The readings taken are:

1. *Weight of the empty r.d. bottle* $= W_1\ gm$
2. *Weight of the r.d. bottle filled with liquid* $= W_2\ gm$
3. *Weight of the r.d. bottle filled with water* $= W_3\ gm$

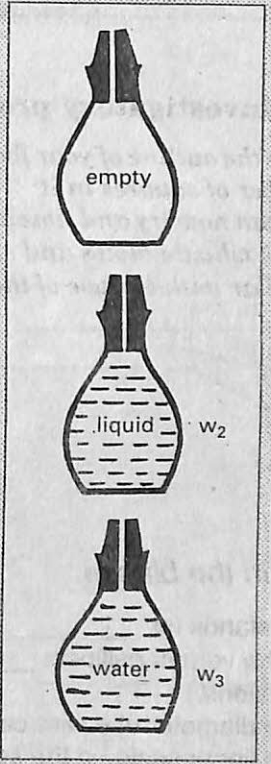
$\therefore$ *weight of liquid alone* $= W_2 - W_1\ gm$

weight of water alone $= W_3 - W_1\ gm$

$$\therefore r.d. = \frac{\text{weight of any volume of liquid}}{\text{weight of an equal volume of water}}$$

$$\frac{W_2 - W_1}{W_3 - W_1}$$

Result : The density of the given liquid is ....



The advantage of weighing the liquid first is that the bottle does not have to be dried during the experiment and there is no need to waste liquid by rinsing a bottle wet with water.

If the mass is measured in gms, then the relative density of the body is numerically equal to its density. Hence first calculate the density in gm/cc and convert it into kg/m³. How should this be done?

Basic concepts

1. ISI stands for Indian Standards Institution.
2. For accurate measurements, (in length) we need instruments like the vernier callipers and screw gauge.
3. The smaller the quantity to be measured, the more accurately it should be measured.
4. Mass can be found to an accuracy of 1/100 of a gram, i.e., a centigram, using a physical balance.
5. Density of a substance is its mass per unit volume.
6. Density = mass/volume; mass = volume x density ; volume = mass/density.
7. The SI unit of density is kg per m^3.

Some investigatory projects/activities

1. *Draw the outline of your foot on a graph paper. Measure the area of your foot by counting the number of squares in it.*
2. *You can now try and time a race using a stop watch. You should start your stop watch as soon as the whistle blows and stop it when the first person crosses the finish line. Make yourself familiar with the use of the stop watch how and to read it before you use it.*

REVISION

I. Fill in the blanks.

1. ISI stands for ________ .
2. In the vernier callipers ________ main scale divisions coincide with ________ vernier scale divisions.
3. The diameter of a wire can be measured with a ________ .
4. The linear scale on the screw gauge is called the ________ .
5. The circular scale is called the ________ .
6. The smallest length that can be measured with a screw gauge is called ________ .
7. ________ is the distance travelled by the screw when the head is rotated once.
8. Pitch = ________
9. If the zeros of the pitch and head scales do not coincide then the screw gauge has a ________ error.
10. The unit of density in the SI system is ________ .

II. State if the following are true or false.

1. The vernier callipers measures correct to $\frac{1}{100}$th of a centimetre.
2. The linear scale on the screw gauge is called the head scale.

3. The distance travelled by the screw when the head is rotated once is called the pitch.

4. In a screw gauge, the least count is $\frac{\text{Pitch}}{\text{No. of division on head scales.}}$

5. If the zero of the head scale is above the reference line on the pitch scale then the error has to be subtracted.

6. If the specific gravity of a substance is 7.8 its density is 7.8 gm/cc.

7. 1 gm/cc is equal to $\frac{1}{1000}$ kg/m³.

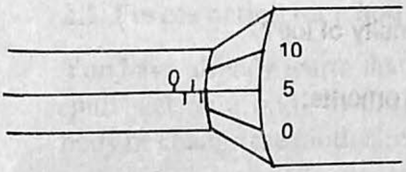
III. Choose the correct answer.

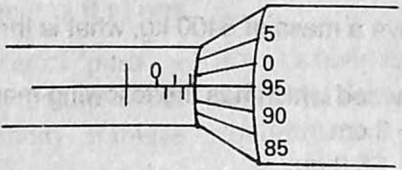
1. If the pitch of a screw which has 100 divisions on the head is 1 mm, the least count is
   a. 1 mm. b. 0.1 mm. c. 0.1 cm. d. 0.01 mm.

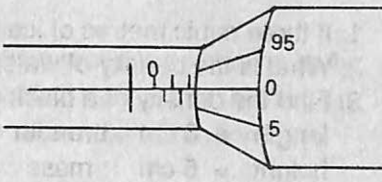
2. If the zero of the head scale is above the zero of the pitch scale there is a
   a. positive zero error. b. negative zero error. c. no zero error.

IV. Write the value of the zero error in a, b and c:

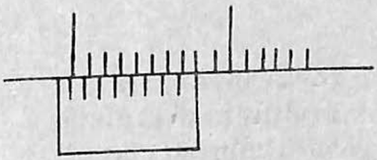
1.

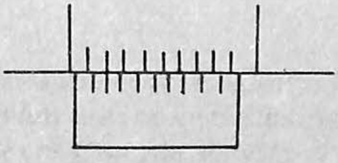


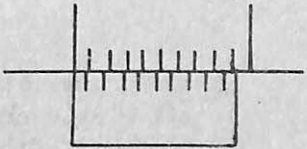




2.



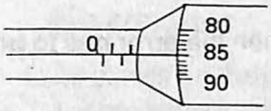


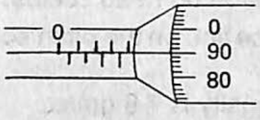


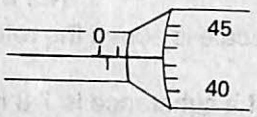
V. Answer briefly :

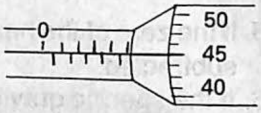
1. What is meant by least count of a screw gauge? How will you determine it?
2. What is meant by zero error of a screw gauge? When is it negative ?
3. What is meant by the pitch of a screw?

4. Note down the following readings in a tabular form. Assume the zero error to be +2 divisions.









5. How will you find the time for one oscillation in a simple pendulum?

VI. Answer the following questions:

1. Describe the screw gauge. How will you take a reading with it?
2. Describe how you will determine the radius of a lead shot using a screw gauge. How will you calculate its volume?
3. Describe an experiment to find the density of a regular solid.
4. Describe an experiment to find the density of an irregular solid.
5. Describe how you will determine the density of a liquid using a relative density bottle.

VII. Answer the following:

1. If three cubic metres of ice have a mass of 5400 kg, what is the density of ice?
2. What is the density of water?
3. Find the density of a block of wood which has the following measurements:
   length = 6 cm breadth = 3 cm
   height = 5 cm mass = 55.8 gm

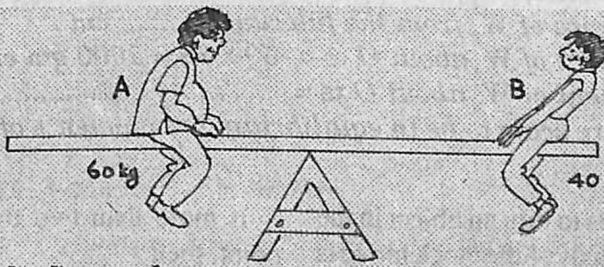
   Write your answer in gm/cc and kg/m^3.
   (Ans: 0.62 gm/cc, 6200 kg/m^3)
4. A specific gravity bottle weighs 14.72 gms when empty, 39.74 gms when filled with water and 44.85 gms when filled with a solution of common salt. Find its density.
   (Ans: 1200 kg/m^3)

2. Mechanics

Forces acting on a body keeping it at rest. - principle of moments- meaning of motion- scalars and vectors- speed, velocity, acceleration- displacement/ time and velocity/ time graphs- equations of motion- acceleration due to gravity- motion in a circle with uniform speed- Newton's laws- streamlining

2.1 Forces acting on a body keeping it at rest

You have already learnt that forces of 'push' or 'pull' act on a body to produce motion of the body or change the motion of the body. If forces act on a body and they produce no change in the motion of the body, then the body is said to be in equilibrium under the action of the forces.



Activity 1: *In the figure above two boys are balanced on a seesaw. The plank is in equilibrium. What are the forces acting on the plank? Do they act parallel to each other? Can you show by arrows the direction of these two forces? Is there any other force acting? Where?*

Activity 2: *Questions to think about:*
In the above seesaw example if A were to move nearer the support what would happen? Which side would go up? In order to produce a balance again, in which direction would B have to move? What are the factors that determine which boy will be effective in turning the plank? About which point will the plank rotate?

1st Factor ....
2nd Factor ....

The above figure can be represented as

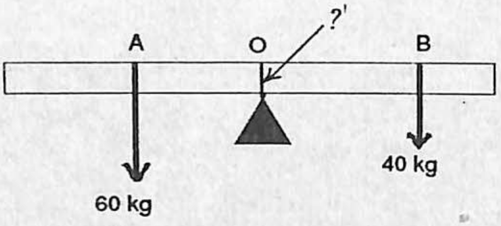
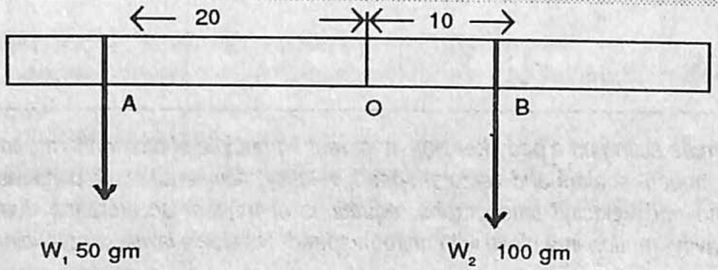


Fig 2.1

We have seen that the effect of the forces at *A* and B is to turn the plank about *O*. What is point *O* called?

The turning effect of a force about a point is called the *moment* of the force about the point. The moment of the force depends on the force acting and its distance from the fulcrum. It is numerically equal to the product of the force and its perpendicular distance from the fulcrum.



Activity 3: *In the figure above we have a metre scale suspended by a string passing through O. The point O is called the ....*
The force acting at A is .... gmf .
The force acting at B is .... gmf .
The distance of W_1 from the fulcrum is .... cm .
The distance of W_2 from the fulcrum is .... cm .
The moment of W_1 about O is = 50 x 20 = 1000 gm cm .
The moment of W_2 about O is = ...= ....
For the metre scale to be in equilibrium the moments of W_1 and W_2 should be ....

A moment which tends to turn an object in the direction in which the hands of the clock move is called the *clockwise* moment. The moment which tends to turn the object opposite to the rotation of the hands of the clock is called the *anticlockwise* moment. For the body to be in equilibrium the clockwise moment = anticlockwise moment.

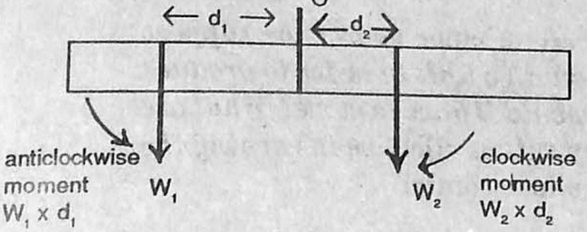


fig 2.2

If more than two forces are acting about a point, then
the sum of the clockwise moments = sum of the anticlockwise moments.

Apart from rotating the body, parallel forces may also move the body in a straight line.

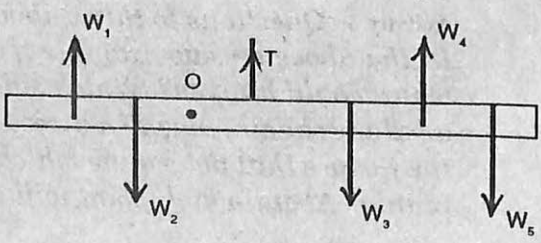


Fig 2.3

For example in the figure 2.3, W_1, T and W_4 act in the upward direction where T is the tension of the string and the forces W_2, W_3 and W_5 act in the downward direction. If the body is to remain in equilibrium

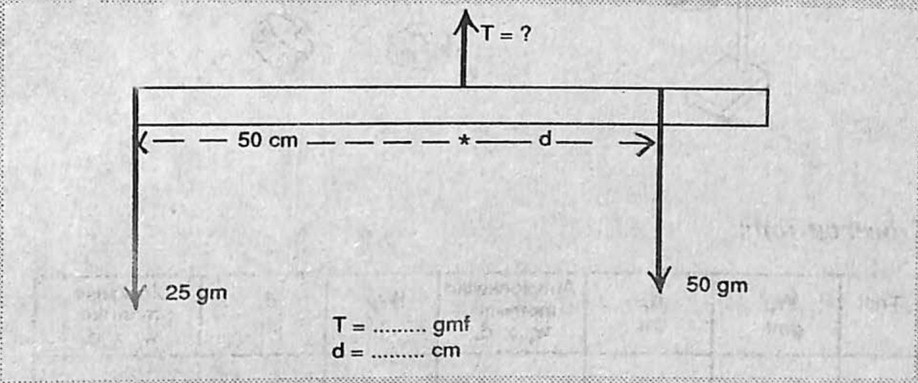
1. The sum of the upward force must be equal to the sum of the downward force.

2. The sum of the clockwise moments must be equal to the sum of the anticlockwise moments.

The above two conditions are referred to as the *law of moments*.

Activity 4: Complete the following.

1. The conditions necessary for the equilibrium of parallel forces are
   (a) The forces in one direction .... the forces in the ....
   (b) To prevent rotation, the sum of the .... moments, equals the sum of the .... moments.



T = ... gmf
d = ... cm

Activity 5: *To verify the law of moments.*

Things needed: 1. A metre scale with a hole drilled on the 50 cm mark. (if this is not available,an ordinary 1m ruler will do).

2. A stand with a support.

3. Small hangers with slotted weights of 50 gm each or weights from weight boxes.

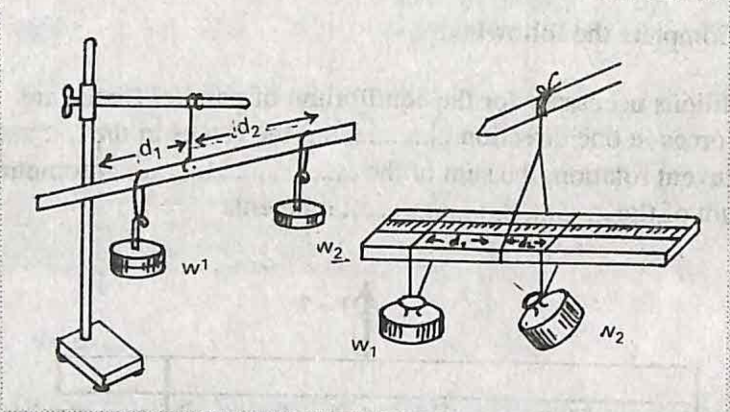
4. Some cotton thread.

Method: 1. Tie a loop of thread around the 50 cm mark of the scale or through the hole and suspend it as shown in the diagram.

2. With the thread, suspend two weights W_1 and W_2 on either side of the 50 cm mark and adjust their positions so that the metre scale is horizontal. Note down the positions of W_1 and W_2 as d_1 and d_2 in the tabular form provided.

3. Repeat the experiment twice, once by changing the distances d_1 and d_2 and then by changing the weights and the distances.

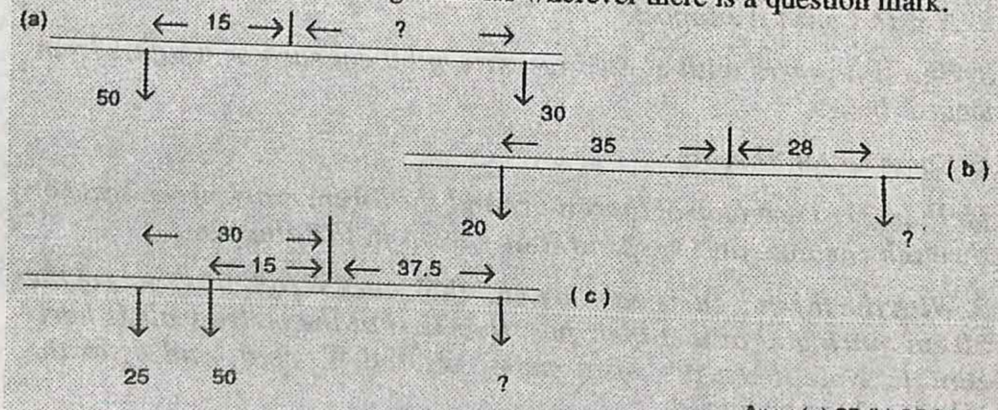
4. Calculate the moments of the force, $W_1 \times d_1$ and $W_2 \times d_2$ in each case. If the values are equal or nearly equal, the principle of moments is verified.



Observations:

Trial	W_1 gmf	d_1 cm	Anticlockwise moment $W_1 \times d_1$	W_2 gmf	d_2 cm	Clockwise moment $W_2 \times d_2$
1						
2						
3						

Activity 6: Supply the missing numbers wherever there is a question mark.



Ans : (a) 25 (b) 25 (c) 40

2.2 Meaning of motion

When a body moves it is said to be in motion. To decide whether or not a body is in motion, it is necessary to see if there is any change in its position with respect to other bodies around it. For example, if the position of a car changes with respect to the houses and trees, then the car is said to be in motion with respect to those bodies.

On the other hand, though the earth is moving around the sun in its orbit, all the objects on the earth move with it and so don't have any change in position with respect to each other. Hence you, and all the objects in the room are said to be at rest with respect to each other.

How can forces be recognized?

A cyclist sets his cycle *in motion* with the help of the force he exerts on the pedals. Cars and other vehicles are driven with the help of engines which exert forces. The football player stops a ball or changes its direction, exerting a force on the ball by using his muscles.

Forces are recognized by their effects. They can accelerate bodies, slow them down, change the direction of motion, or deform them.

Activity 7: Test your knowledge.

1. Motion along a straight line is called ________ motion.

2. Motion along a curved path is ________ motion.

3. Motion such as seen in a spinning top or an electric fan is called ________ motion.

4. The pendulum of the clock has ________ motion.

5. Motion which is irregular or haphazard is called ________ motion.

6. Motions which occur again and again are called ________ motion.

7. If repetitive motion takes place after regular intervals of time it is called ________ motion.

8. All periodic motions are ________.

Allot 1 mark for each correct answer.

Answers: 1. rectilinear. 2. curvilinear. 3. rotatory. 4. oscillatory. 5. random. 6. repetitive. 7. periodic. 8. repetitive.

If your score is 8 - 10 Very Good. 6 - 8 Good. 5 Fair. Less than 5 - You need to revise your previous work !

2.3 Scalars and vectors

Most of the quantities used in science are classified as either *scalar* or *vector* quantities. A scalar quantity is one which has only magnitude (or size). A vector quantity has both magnitude and direction. When we say a substance weighs 50 gm or a tank has 500 litres of petrol, we are dealing with scalar quantities. On the other hand, when we are talking of velocity, acceleration, force, in addition to the magnitude we also have to state the direction. These quantities are therefore vectors.

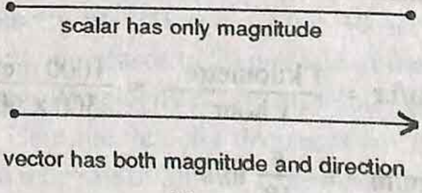

scalar has only magnitude
vector has both magnitude and direction

Fig. 2.4

A boat or a steamer cannot be navigated unless the direction is specified in addition to the speed. Similarly, an aeroplane cannot be piloted unless the direction is specified. Hence, the motion of the boat or plane is completely described by its speed (magnitude) and direction.

Activity 8: *Place the following list of physical quantities, under the headings given below :*

mass
length
acceleration
time
force
density
volume
weight
velocity
area
speed
displacement

Scalars	*Vectors*
1.	....
2.	....
3.	....
4.	....
5.	....
6.	....

2.4 Speed, velocity, acceleration

SPEED

Mechanics is the study of objects or bodies in motion. The distance a body moves in unit time is called *speed*. Speed is defined as the rate at which a body changes its position. When we say a car is travelling at the rate of 45km/hr, it means that the car travels 45 km in one hour. Or,

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}} = \text{m/s}$$

In the SI system the unit of speed is metres per sec (m/s). For a car or a train or a bullet, which covers thousands of metres in an hour, it is more convenient to express speed in kilometres per hour.

$$1\text{km/hr} = \frac{1 \text{ kilometre}}{1 \text{ hour}} = \frac{1000 \text{ metres}}{360 \times 60 \text{ secs}}$$

$$1\text{km/hr} = \frac{5}{18} \text{ m/s}$$

So if we want to convert km/hr into metres sec., we have to multiply by 5/18.

VELOCITY

When we specify the rate at which a body is travelling in a given direction then we use the terms velocity not speed. Let us say a body is moved from a place A to B within a time t seconds. This displacement may take place in a number of ways.

It can be moved along the path ACB to B or along the path ADB to B. The speed of the body would be

$$= \frac{\text{distance } ACB}{t} \quad \text{if it moved along } ACB,$$

or

$$= \frac{\text{distance } ADB}{t} \quad \text{if it moved along } ADB.$$

Hence, speed depends on the actual distance travelled in unit time.

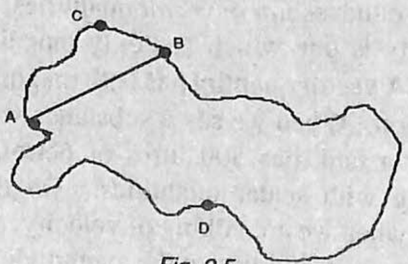


Fig. 2.5

If, however, we consider the change of position of the body from *A* to *B* in the direction *AB*, the distance *AB* travelled in the direction *A* to *B* or *B* is called the *displacement* of the body. Displacement of the body is defined as *the distance travelled in a particular direction*. Velocity is defined as *the rate of displacement of a body*.

$$\text{Or, velocity} = \frac{\text{displacement}}{\text{time}} \quad \text{m/s}$$

or displacement (s) = velocity (v) × time (t) or,

$$s = vt$$

$$v = \frac{s}{t}$$

$$t = \frac{s}{v}$$

Thus, a train may be said to be travelling at a velocity of 45 kilometres per hour due north. If we consider the motion of a train on a circular track we will note that although its speed is constant, its velocity changes because its direction constantly changes.

Uniform velocity: The velocity of a body is said to be *uniform* when it covers equal distances in equal intervals of time however small the intervals may be, the direction remaining constant. The velocity of a body is said to be *variable* when it passes over unequal distances in successive equal intervals of time or changes its direction of motion. Thus, a train has a uniform velocity of 6 metres per second if it regularly moves a distance of 6 metres in one second in a constant direction. If a train does not regularly traverse a distance of 6 metres in a second, but instead halts at stations, then its velocity at the time of leaving a station or reaching it, will be different from its velocity between the stations and so we say that it has a variable velocity.

A body moving in a curved path, such as the hands of a clock, has constant speed but not a uniform velocity because its direction changes continually. Uniform velocity is measured by the displacement in some unit of time.

In the case of a body moving with a variable velocity we speak of its *average velocity*. In this case, the total distance travelled by a body is divided by the time taken to travel this distance.

When the velocity of a moving body is not constant, i.e., it increases with time, it is said to have *acceleration*.

Acceleration is defined as the *rate of change of velocity with time*.

or acceleration (a) =

$$\frac{\text{change in velocity}}{\text{time taken}} = \frac{m}{s^2}$$

When equal changes of velocity take place in equal intervals of time, the acceleration is said to be *uniform*. For example, if a body has a velocity of 50 m/s at any instant, after 10 seconds its velocity is found to be 100 m/s, and after the next 10 seconds its velocity is found to be 150 m/s and so on. The velocity here changes by 50 m/s every 10 seconds and so is called uniform acceleration.

Acceleration (a) =

$$\frac{\text{change in velocity } 50\text{ m/s}}{\text{time taken } 10\text{s}}$$

$$= 5\frac{m}{s}/s = 5\text{ m/s}^2$$

If the velocity of a body gradually decreases as time goes on, it is said to have *retardation* or *negative acceleration* (*deceleration*).

For example, consider a body moving with a velocity of 100 m/s. After 10 seconds its velocity decreases to 80 m/s and in the next 10 seconds its velocity decreases to 60 m/s, and so on. Here the velocity decreases by 20 m/s in equal intervals of time of 10 seconds. Hence the retardation is

$$a = \frac{2}{10} = 2\text{ m/s}^2 \text{ or, acceleration} = -2\text{ m/s}^2$$

Activity 9 : *Fill up the blanks wherever they occur.*

Initial velocity m/s	Final velocity m/s	time s	acceleration m/s^2
5	15	2	...
...	30	5	4
12	...	8	3
4.5	21	...	3.3

Calculation of resultant velocity : Sometimes a particle or a body may have two different velocities at the same time. How can this happen?

Consider a man walking on the deck of a ship. The ship moves with a certain velocity in a given direction and the man on the deck has his own velocity as he moves about on the deck. Hence the man has two velocities.

Activity 10: *Make a list of examples of bodies having different velocities at the same time.*

To find the resultant of two velocities we use the law of parallelogram of velocities which states: *If a particle simultaneously possesses two velocities represented in magnitude and direction by the two sides of parallelogram drawn from a point, they are equivalent to a single resultant velocity represented in magnitude and direction by the diagonal of the parallelogram passing through that point.*

Let *OA* and *OB* represent two velocities v_1 and v_2, respectively, of a particle at *O*. Complete the parallelogram *OACB* and draw the diagonal *OC*. The length of the diagonal represents the magnitude of the resultant velocity and the angle θ gives the direction it makes with the horizontal. α is the angle which v_1 and v_2 make with each other.

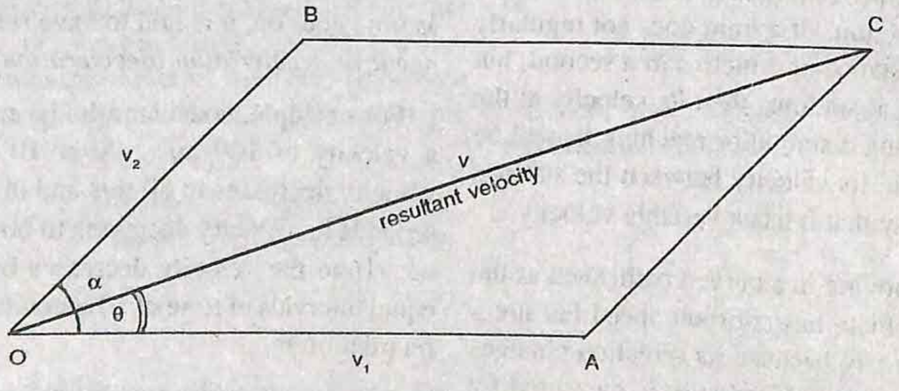
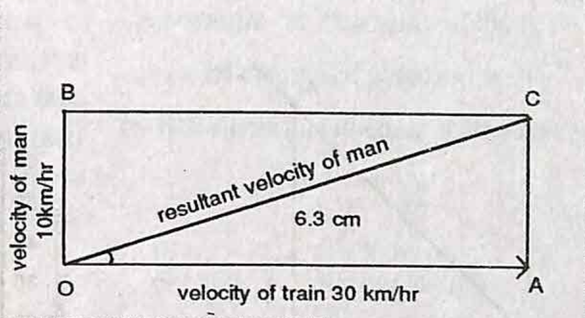


Fig. 2.6

Activity 11: *Example:*

A person sits on a railway train going forward at a speed of 30 km/hr. If he now gets up and walks across the carriage floor with a velocity of 10 km per hr what is his resultant velocity with respect to the track?

1. *Choose a convenient scale to represent velocity such as 1cm = 5 km/hr*
2. *Draw OA to represent 30 km/hr., i.e., 30/5 = 6 cm.*
3. *Draw OB perpendicular to OA to represent the motion across the carriage at 10 km/hr. i.e. 10/5 = 2 cm.*



4. *Complete the parallelogram OACB which in this case is a rectangle.*
5. *Measure the diagonal OC which is the resultant velocity. OC = 6.3 cm.*
6. *Since 1 cm represents 5 km/hr 6.3 cm represents 6.3 x 5 = 31.5 km/hr.*
7. *Measure the angle θ which the resultant velocity makes with the horizontal. $\theta = 20°$*
8. *The resultant velocity of the man with respect to the track is 31.5 km at an angle of 20° with the horizontal.*

2.5 Displacement/time and velocity/time graphs

It is often convenient to use a graph to represent motions.

TIME-DISTANCE GRAPH

A time-distance graph is one in which the distance covered is plotted upwards along the Y-axis against time on the X-axis. For a body moving with uniform velocity, the graph is a straight line. If the body accelerates so that its

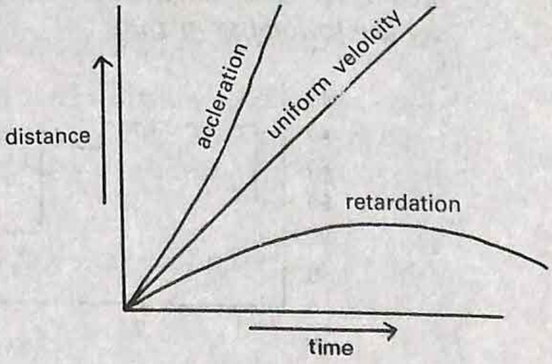


Fig 2.7 Time-distance graph

velocity increases with time the graph curves upwards. If it slows down i.e., if it is retarded (negative acceleration) the graph curves downwards.

Now if we take a point *A* on the graph and drop a perpendicular *AB* on the time axis (Fig.2.8), then, *AB* represents the distance moved in time *OB*.

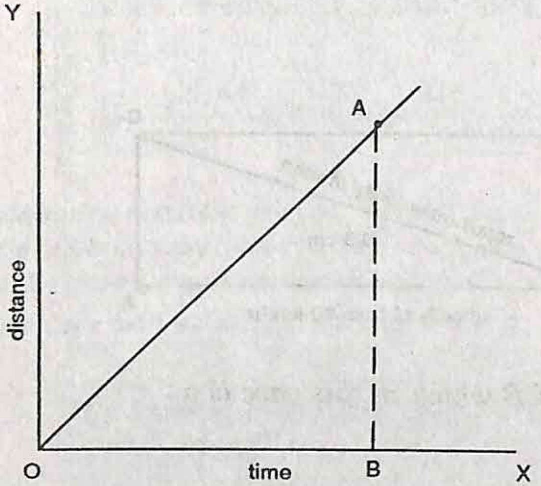


Fig. 2.8

$$\text{Therefore velocity} = \frac{\text{distance}}{\text{time}} = \frac{AB}{OB}$$

$\frac{AB}{OB}$ is known as a *gradient* or *slope* of line OA.

VELOCITY-TIME GRAPHS

1. For a body moving with constant speed, we have seen

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{or},\ v = \frac{s}{t}$$

$$\text{or},\ s = vt$$

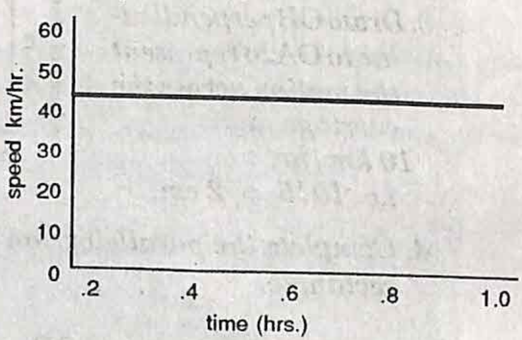
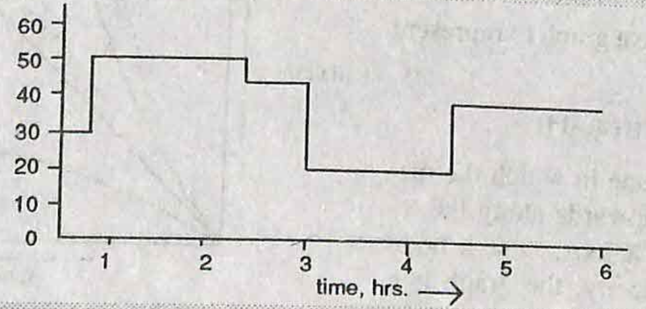


Fig. 2.9

Activity 12: *From the following data, plot a time-distance graph. Deduce the velocity at the end of 0.5 sec.*

Time - sec	0	0.2	0.4	0.6	0.8	1.0
Distance (m)	0	7.1	21.3	42.6	71.0	106.5

Activity 13: *Describe the motion of the car whose motion is represented by the following graph.*



For a car moving with a speed of 45 km/hr, at any instant its speed is the same, i.e., 45 km/hr. So, a speed-time graph to represent this would be as shown in Fig. 2.9 .

Look at the graph (Fig.2.9). What is the speed after 1/2 hour? after 2 hours? Is it constant? What can you conclude if the graph is a straight line parallel to the X-axis?

A car starting from rest, accelerates to a velocity of 30 km/hr in 15 min. It travels with this constant speed for 25 min. The brakes are then applied and it comes to rest with uniform retardation in 10 minutes. We can draw a graph to represent its motion as in fig. 2.10.

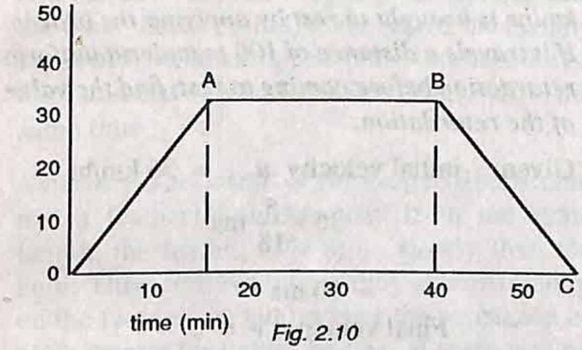


Fig. 2.10

OA→ accelerated motion for 15 minutes
initial velocity = 0,
final velocity = 30 km/hr.

AB → constant velocity for 25 minutes.
velocity = 30 km/hr.

BC→ retarded motion for 10 minutes.
initial velocity = 30 km/hr,
final velocity = 0.

2.6 Equations of motion

Let us consider a body whose initial velocity is u, moves for a time t with a constant acceleration a, and so acquires a final velocity v. It moves a distance s in time t. Now, from the definition of acceleration the change in velocity $= v - u$.

$$\therefore \text{ rate of change of velocity } = \frac{v-u}{t}$$

by definition this is equal to the acceleration a.

$$a = \frac{v-u}{t} \quad \text{..........} \text{ (a)}$$

$$\text{or,} \quad v - u = at$$

$$\text{or,} \quad v = u + at \quad \text{..........} \text{ (1)}$$

Now, distance = average velocity x time

$$s = \left(\frac{u+v}{2} \times t\right) \quad \text{..........} \text{ (b)}$$

Substituting the value of v from (1) we get

$$s = \left(\frac{u+u+at}{2}\right) \times t$$

$$= \left(\frac{2u+at}{2}\right) \times t$$

Activity 14: *Draw a graph to depict the following:*

A car starting from rest accelerates with uniform acceleration to 45 km/hr in 10 min. Its velocity remains constant for the next half an hour. The brakes are applied and the vehicle comes to rest in the next 15 minutes.

Also find from the graph, the velocity five minutes after the start and five minutes before the end.

$$= \left(u + \frac{at}{2}\right) \times t$$

$$s = ut + \frac{1}{2}at^2 \qquad .... \qquad .... \; (2)$$

From the expression (a) we have

$$v - u = at \qquad ... \qquad (c)$$

and from (b) we have

$$s = \frac{u + v}{2} \times t$$

$$2s = (u + v) \times t$$

$$u + v = \frac{2s}{t} \qquad .... \; (d)$$

Multiplying (c) by (d)

$$(v - u)(v + u) = a\cancel{t} \times \frac{2s}{\cancel{t}}$$

$$v^2 - u^2 = 2as \qquad .... \qquad (3)$$

The equations (1), (2) and (3) are referred to as the *first*, *second* and *third equations of motion* respectively.

The following problems based on the three equations of motion have been worked out for you. Copy the problems into your note book and work them out independently. Then check your working with the solutions.

Problem 1: *A car accelerates from rest to 30 km/hr in 30 sec. What is its acceleration? How far does it go in this time?*

Given: initial velocity $u = 0$

final velocity $v = 30$ km/hr

$$= 30 \times \frac{5}{18} \text{ m/s}$$

$$= \frac{25}{3} \text{ m/s}$$

time taken $t = 30$ s

$a = ?$

$s = ?$

From the first equation of motion we have

$$v = u + at$$

$$\frac{25}{3} = 0 + a \times 30$$

$$30\,a = \frac{25}{3}$$

$$a = \frac{25}{90}$$

or, $a = .28 \text{ m/s}^2$

From the second equation of motion we have

$$s = ut + \frac{1}{2}at^2$$

$$= 0 \times 30 + \frac{1}{2} \times \frac{25}{90} \times 30^2$$

$$= 0 + \frac{1}{2} \times \frac{25}{90} \times 30 \times 30$$

$$s = 125 \text{ m}$$

Problem 2: *A train travelling with a speed of 36 km/hr is brought to rest by applying the brakes. If it travels a distance of 100 m under a uniform retardation before coming to rest, find the value of the retardation.*

Given: initial velocity $u = 36$ km/hr

$$= 36 \times \frac{5}{18} \text{ ms}^{-1}$$

$$= 10 \text{ ms}^{-1}$$

Final velocity $v = 0$

distance $s = 100$ m

$a = ?$

From the 3rd equation of motion we have

$$v^2 - u^2 = 2as$$

or

$$a = \frac{v^2 - u^2}{2s}$$

$$= \frac{0 - 100}{2 \times 100}$$

$$= -\frac{1}{2}$$

$$a = -.5 \text{ ms}^{-2}$$

or *the retardation* = 0.5 ms^{-2}.

2.7 Acceleration due to gravity

The earth attracts all bodies on or near its surface, and this attraction is called *gravity* or *gravitational attraction*. Under the action of gravity, all bodies, when free to move, move towards the centre of the earth. For a body falling freely under gravity the motion is one with a constant acceleration. This constant acceleration developed in freely falling bodies is called the *acceleration due to gravity.* It is represented by the letter 'g' and its value is usually taken as 980 cms^{-2} or 9.8 ms^{-2}.

This value varies slightly from place to place on the surface of the earth because the earth is not a sphere but is slightly flattened at the poles.

Galileo's experiment : In order to show that all bodies fall with the same acceleration, Galileo, who was teaching in the University of Pisa, took two balls of iron, one weighing 100 pounds, and the other, half a pound, to the top of the leaning tower of Pisa, and dropped them simultaneously. He found that they both reached the ground at the same time.

Newton's experiment: If you drop a 10 paise coin and a feather simultaneously from the same height, the feather falls more slowly than the coin. This is not because gravity acts differently on the two bodies but because the resistance of air is greater for lighter bodies. If there was no air, both the feather and coin would reach the ground simultaneously. Newton demonstrated this in his famous guinea and feather experiment.

He placed a guinea and a feather inside a long glass tube and removed the air from it by connecting the opening to an exhaust pump. When there was no air inside, it was seen that if the tube was suddenly inverted, the coin and feather fell together. On re-introducing air into the tube the feather fell more slowly than the coin.

This experiment confirmed that in the absence of air all bodies fall with the same acceleration.

The three equations of motion are also used in calculations involving motion under gravity. The acceleration a in the equations are replaced by

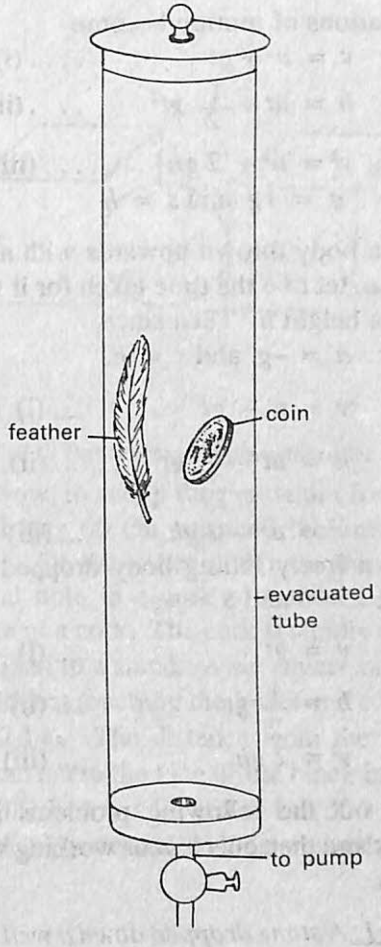


Fig. 2.11 Newton's feather and coin experiment

the acceleration due to gravity g. When writing the equations for motion under gravity, the following points must be remembered :

1. When a body is thrown downwards, the acceleration due to gravity is *positive*.
2. When a body is thrown upwards (against gravity) the acceleration due to gravity is *negative*.
3. For a freely falling body the initial velocity is *zero*.

(1) For a body thrown downwards with an initial velocity u, let t be the time taken for it to fall through a height h.

The equations of motion become

$$v = u + gt \quad \ldots.\text{(i)}$$

$$h = ut + \frac{1}{2}gt^2 \quad \ldots.\text{(ii)}$$

$$v^2 = u^2 + 2gh \quad \ldots.\text{(iii)}$$

since, $a = +g$ and $s = h$

(2) For a body thrown upwards with an initial velocity u, let t be the time taken for it to move through a height h. Then since

$a = -g$ and $s = h$.

$$v = u - gt \quad \ldots.\text{(i)}$$

$$h = ut - \frac{1}{2}gt^2 \quad \ldots.\text{(ii)}$$

$$v^2 = u^2 - 2gh \quad \ldots\text{(iii)}$$

(3) For a freely falling body dropped from a height h, $u = 0$ and $a = +g$.

$$v = gt \quad \ldots.\text{(i)}$$

$$h = \frac{1}{2}gt^2 \quad \ldots.\text{(ii)}$$

$$v^2 = 2gh \quad \ldots.\text{(iii)}$$

Work out the following problems in your notebook and then check your working with the solutions.

Problem 1: A stone dropped down a well hits the water 4 seconds later. Find the depth of the well and the velocity with which the stone strikes the water.

Given $t = 4$ sec.

For a freely falling body

$g = 9.8\ \text{ms}^{-2}$ $h = ?$ $v = ?$

$$h = \frac{1}{2}gt^2$$

$$= \frac{1}{2} \times 9.8 \times 4^2$$

$$= \frac{1}{2} \times 9.8 \times 16$$

$$= 78.4\ \text{m}$$

$$v = gt$$

$$= 9.8 \times 4$$

$$= 39.2\ \text{ms}^{-1}$$

Ans : Depth of the well = 78.4 m; Velocity = 39.2 ms^{-1}.

Problem 2: A stone is thrown from a cliff vertically downwards with a velocity of 5 ms^{-1}. The acceleration due to gravity is 9.81 ms^{-2}. How far does it go in 2 seconds and what is its velocity then?

$u = 5\ \text{ms}^{-1}$

$g = 9.81\ \text{ms}^{-2}$

$t = 2$ sec

$h = ?$

$v = ?$

From the first equation of motion we know that

$$h = ut + \frac{1}{2}gt^2$$

$$= 5 \times 2 + \frac{1}{2} \times 9.81 \times 4$$

$$= 10 + 19.62$$

$$= 29.62\ \text{m}$$

$$v = u + gt$$

$$= 5 + 9.81 \times 2$$

$$= 5 + 19.62$$

$$= 24.62\ \text{ms}^{-1}$$

Ans : velocity = 24.62 ms^{-1}
height = 29.62 m.

THE SIMPLE PENDULUM

The simple pendulum is an instrument for measuring time. Galileo showed that the time of oscillation of a pendulum depends on the length of the pendulum and not on the weight of the bob or on the extent of swing (provided the swing is small).

A simple pendulum may be considered to be a heavy particle suspended by a weightless inextensible thread. In practice, a simple pendulum consists of a small heavy metal sphere called the bob, freely suspended by a very thin and tortionless thread.

The distance between the point of suspension and the centre of gravity of the bob is called the *effective length* of the pendulum. One complete

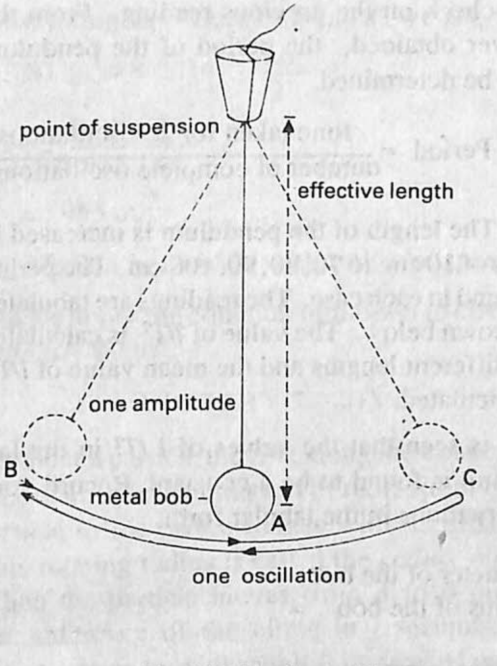


Fig. 2.12 Simple pendulum

to and fro motion is called one *oscillation*. Thus, when the bob starts from *A*, moves to *B*, back to *A*, then to *C* and back to *A* it performs one complete oscillation. The maximum displacement of the bob (*AB* or *AC*) on either side of its position of equilibrium is called the *amplitude* of oscillation. The time taken to perform one complete oscillation is called the *time period* or *period* of oscillation.

I. *Adjusting the length of the pendulum*: Remember that the length of the simple pendulum is the distance between the point of suspension and the centre of gravity of the bob.

(1)To adjust the length, first the radius of the bob must be determined.

This may be done by placing the bob between the parallel faces of the two blocks, the faces being tangential to the surface of the bob (Fig. 2.13). The distance between the inner sides of the block is measured with a scale. This gives the diameter from which the radius '*r*' is calculated. (You may also use vernier callipers to determine the diameter.)

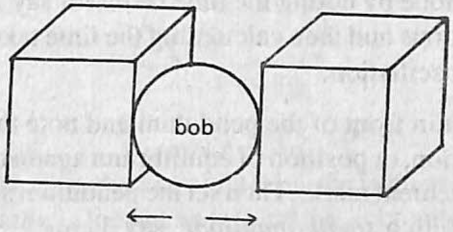


Fig. 2.13 Determining the diameter of the bob

(2) Now, to set up the pendulum for a given length say 60 cm, suspend the bob from a thread, let the other end pass through the central hole in a cork or between the split halves of a cork. The cork is rigidly clamped and fixed to a stand. A set square or a block is held just touching the lower end of the bob (Fig.2.14). The distance from the point of suspension to the face of the block in contact with the bob is adjusted to be (60 + *r*). The length of the pendulum is now exactly 60 cm.

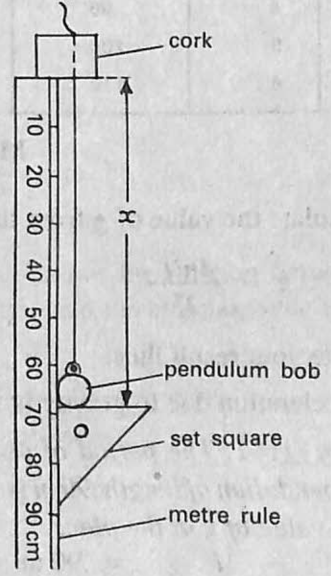


Fig. 2.14 Adjusting the length of the pendulum

II. *Determining the period of the pendulum :* Since it is difficult to accurately determine the time taken for a single oscillation, this is generally done by noting the time taken for say 25 oscillations and then calculating the time taken for one oscillation.

Sit in front of the pendulum and note the rest position, or position of equilibrium against some convenient mark. Then set the pendulum swinging with a *small amplitude*, say 3 cm.

Time the oscillation by counting 'nought' as the bob passes through its rest position and simultaneously start a stop-clock counting one, two, three, etc. each time the bob passes through its rest position in the same direction. In this way, find the time of 25 oscillations for a given final length. In each case the timing is repeated as a check on the previous reading. From the answer obtained, the period of the pendulum may be determined.

III. Period $= \dfrac{\text{time taken for 25 oscillations}}{\text{number of complete oscillations}}$

IV. The length of the pendulum is increased in steps of 10 cm, to 70, 80, 90, 100 cm. The period is found in each case. The readings are tabulated as shown below. The value of l/T^2 is calculated for different lengths and the mean value of l/T^2 is calculated.

It is seen that the values of l/T^2 in the last column is found to be a constant. Record your observations in the tabular form.

Diameter of the bob =

Radius of the bob =

Serial No.	Effective length $\times 10^{-2}$ m	Time for 25 oscillations I sec	II sec	Mean period sec.	$\frac{l}{T^2}$ m/s²
1	60				
2	70				
3	80				
4	90				
5	100				
6	110				

Mean l/T^2 = ...m/s²

V. Calculate the value of g from the relation

$$g = \frac{4\pi^2 l}{T^2}$$

VI. State your result thus:

The acceleration due to gravity is .... ms^{-2}.

Problem 1: *1. The period of oscillation of a simple pendulum of length .90 m is 1.9 s. Calculate the value of g at the place.*

l = .90 m
T = 1.9 s
g = ?

$$g = 4\pi r^2 \frac{l}{T^2}$$
$$= 4 \times (3.14) \times \frac{.9}{(1.9)^2}$$
$$= 9.83 \text{ ms}^{-2}$$

2. Find the length of the seconds pendulum at a place where g = 9.81 ms^{-2}.

g = 9.81 ms^{-2}
T = 2 s (Seconds pendulum)
l = ?

$$g = 4\pi r^2 \frac{l}{T^2}$$

Substituting the values of g and T, we get

$$9.81 = 4 \times (3.14)^2 \frac{l}{2^2}$$

$$l = \frac{9.81 \times 2^2}{4 \times (3.14)^2}$$

$$= .995 \text{ m.}$$

2.8 Motion in a circle with uniform speed

Can we apply the equation of motion to circular motion? Why?

ANGULAR VELOCITY

Consider a particle moving along the circumference of a circle of radius r. The radius joining the particle to the centre rotates with the particle. This rotating radius is called the *radius vector*. When the particle moves from A to B on the circumference of the circle in t seconds, the radius vector turns through θ or sweeps out an angle θ in the same time. The rate at which the radius vector sweeps the angle is called the *angular velocity* of the particle, i.e., *the angle described by the radius vector in one second.* Hence, the angular velocity (ω) omega

$$\omega = \frac{\theta}{t}$$

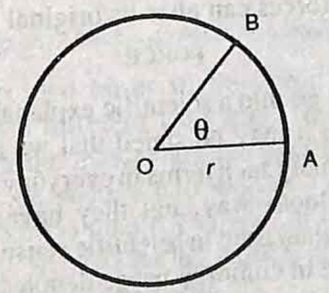


Fig. 2.15

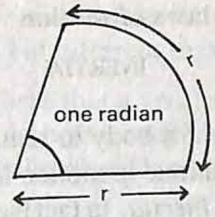


Fig. 2.16 A radian

In the SI system of units an angle is measured in *radians*. One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle.

Hence the unit of angular velocity is radians per sec.

If the distance $AB = s$, then the linear velocity v

$$= \frac{\text{distance}}{\text{time}} = \frac{s}{t}$$

$$\text{Now, angle} = \frac{\text{arc}}{\text{radius}}$$

$$\text{or } \theta = \frac{AB}{r} = \frac{s}{r}$$

$$\text{or } s = r\theta$$

Substituting this value of s in the expression for linear velocity

$$v = \frac{s}{t}$$

$$= \frac{r\theta}{t}$$

$$\text{but } \frac{\theta}{t} = \omega$$

$$\therefore v = r\omega$$

This equation shows the relation between the linear velocity v and the angular velocity ω.

Activity 15: *Complete the following list*

	Linear motion	Circular motion
1.	Ball rolling on the ground.	Merry-go-round
2.		
3.		
4.		
5.		

2.9 Newton's laws of motion

INERTIA

The tendency of a body to remain at rest or, if moving, to continue in motion in a straight line, is described as *inertia*. In fact Newton's first law of motion is sometimes called 'the law of inertia'. The mass of a body is the measure of its inertia.

The following are practical illustrations of inertia at rest and inertia in motion.

1. Inertia at rest

Activity 16 a: *Stack up a pile of books. Grasp the one at the bottom of the pile. Can you remove it without upsetting the whole pile on top?*

Activity 16 b: *Scoop up a spadeful of dry earth. Now pitch the earth away from you. Observe that when the spade stops the earth flies on because of inertia.*

2. Inertia of motion

a. A marble rolling on the floor comes to rest after a while. This is because of the force of friction opposing the motion. If the floor and marble were perfectly smooth the marble would continue to roll until it is stopped.

b. The planets move around the sun due to the attracting force of the sun. Since they move in vacuum (space) there is no opposing force to stop them. Hence their motion is so amazingly uniform that no remarkable change in motion has ever been detected. If, however, the sun's attraction were suddenly removed they would continue their motion in a straight line tangential to their orbit.

NEWTON'S FIRST LAW OF MOTION

An Italian scientist Galileo Galilee was the first to observe various bodies in motion. Later on, the English scientist, Sir Isaac Newton (1642-1727), included Galileo's observations in his laws of motion.

Every body continues in its state of rest or of uniform motion in a straight line unless compelled by some external force to change that state.

Everybody knows that objects at rest do not begin to move by themselves. To move them some kind of a force has to be applied to them. But it is not immediately obvious that a body moving with a uniform velocity in a straight line tends to keep on moving for ever without coming to rest. This is because there are various forces acting on this object, which slowly retard the motion of the object and bring it to a stop.

If a body is moving with uniform speed along a straight line, it keeps on doing so and needs no force to keep up its motion. Only external opposing forces can alter its original motion.

FORCE

Before we go into a scientific explanation of the term *force* it may be stated that we are accustomed to many such terms in everyday conversation in a loose way, but they have a special meaning when used in scientific sense. Thus the word force in common usage denotes a push or pull, but what is the scientific meaning of the word *force* ? To get at this, a careful consideration of *what a force can do* is necessary.

Newton's first law of motion provides the scientific explanation. The first Law states that *every body continues in its state of rest or of uniform motion in a straight line unless compelled by some external force to act otherwise.* Thus, if the body is already moving, a force may alter its speed, or alter its direction of motion or else bring it to rest. Thus *force* can be defined as follows:

Force is that which changes or tends to change a body's state of rest or uniform motion in a straight line.

MOMENTUM

The momentum of a body is defined as the *quantity of motion* possessed by a moving body and depends on the mass of the body and its velocity. This is clear from the following illustrations.

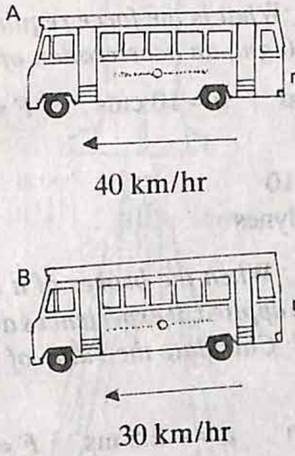


Fig. 2.17 Motion depends on velocity

Consider two buses of the same mass but moving with different velocities. It is evident that though the masses are the same, a greater force will be required to stop *A* (which has greater velocity) than *B* (which has less velocity). Hence we see that the motion of the buses depends on their velocities.

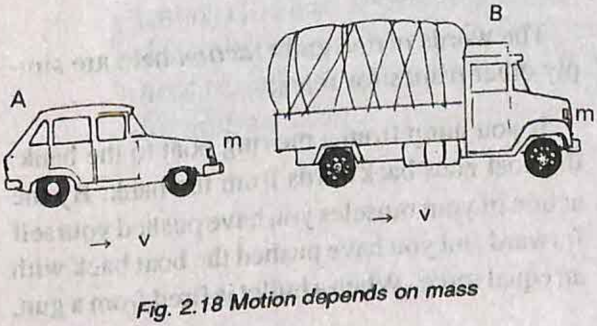


Fig. 2.18 Motion depends on mass

Now consider two vehicles *A* and *B* having the same velocities but different masses.

It is evident here that a greater force will be required to stop the heavier vehicle *B*. Hence, the motion of the bodies depends on their respective masses.

Thus the motion of a body depends on its mass (m) and velocity (v). The product of mass and velocity (mv) is called the *momentum* of the body.

$$\text{momentum} = mv \text{ kg ms}^{-1}$$

NEWTON'S SECOND LAW OF MOTION

Newton realised the important connection between force and momentum, and this is expressed in his *second law of motion.*

The second law of motion states that *the rate of change of momentum of a body is directly proportional to the impressed force and takes place in the direction of the force.*

You have already learnt that the first law of motion gives us the definition of force. The second law of motion tells us how that force is measured.

Suppose a body of mass 'm' has a velocity 'u'. After 't' seconds let its velocity be 'v'.

The initial momentum

$$= \text{mass} \times \text{initial velocity} = mu$$

The final momentum

$$= \text{mass} \times \text{final velocity} = mv$$

$\therefore$ The change in momentum in t seconds

$$= mv - mu$$

$\therefore$ The change in momentum in 1 second

i.e. the rate of change of momentum

$$= \frac{mv - mu}{t} = m\left(\frac{v - u}{t}\right)$$

But $\frac{v - u}{t}$ is the rate of change of velocity i.e. the acceleration a of the body.

∴ The rate of change of momentum $= ma$

By the second law of motion, the force (F) acting is proportional to the rate of change of momentum:

$$\text{or } F \propto ma$$

To remove the proportionality sign, we multiply the right hand side by a constant:

$$F = kma$$

where k is a constant of proportionality.

The unit of force is defined as the force required to produce an acceleration of 1 unit while acting on a body of mass 1 unit. Substituting $F = 1$, $m = 1$ and $a = 1$ in the relation $F = kma$, we find that k also equals 1. Thus we get

$$F = ma$$

In the C.G.S. system of units, the unit of force is the *dyne*. A dyne is that force which, acting on a mass of 1 gm, produces an acceleration of 1 cms^{-2}.

In the SI system of units, force is measured in *newtons*. A newton is that force which, when acting on a mass of 1 kg, produces an acceleration of 1 ms^{-2}.

Thus, in the C.G.S. system $F = ma$ dynes
in the SI system $F = ma$ newtons.

Distinction between mass and weight : The mass of a body is the quantity of matter contained in the body. It is a measure of the inertia of the body and is measured in the units of mass, i.e., either in gm or in kg.

The weight of a body is the force with which the earth attracts the body. Weight is measured in the units of force, i.e., dynes or newtons. The acceleration of freely falling bodies is the acceleration due to gravity g. Hence, the weight which is the force of gravity

= mass x acceleration due to gravity.

i.e., $W = mg$.

The mass of a body remains constant wherever the body may be. Since the weight of a body depends on g, it is not constant, and varies depending on its position on the earth's surface.

WEIGHTLESSNESS

A person will feel 'weightless' when the resultant force acting on him is zero. This is possible in a satellite. A satellite moving in a circular orbit tends to move away from the centre of the orbit (earth). The force acting on a body in circular motion tending to pull it away from the centre is called the *centrifugal force*. This force acts in a direction opposite to the direction in which his weight acts and so he feels weightless.

Problem 1 :*What is the force required to give a mass of 500 gm, an acceleration of 10 cms^{-2} ?*

$m = 500$ gm $a = 10\ \text{cms}^{-2}$ $F = ?$

$F = ma$
$= 500 \times 10$
$= 5000$ dynes

Problem 2 : *When the brakes of a car of mass 1000 kg are applied, it experiences a retardation of 2.5 ms^{-2}. Calculate the value of the braking force.*

$m = 500$ gm $a = -2.5\ \text{ms}^{-2}$ $F = ?$

$F = ma$
$= 1000 \times -2.5$
$F = -2500\ N$

F is negative here because the force applied is opposite to the direction of motion.

NEWTON'S THIRD LAW OF MOTION

The law states that *every action has an equal and opposite reaction.*

The words *action* and *reaction* here are simply other names for force.

If you jump from a moving boat to the bank, the boat goes backwards from the bank. By the action of your muscles you have pushed yourself forward and you have pushed the boat back with an equal force. When a bullet is fired from a gun, the explosive charge pushes the bullet forward with a high velocity. The gun is pushed backward through a small distance. This is known as *recoil*.

The discharge of a rocket is due to combustion (burning) of the fuels inside it. A stream of gas is given off downward with great force; the rocket shoots upward due to the reaction, which is equal and opposite to the downward force. While considering the third law of motion it should be noted that:

1. The reaction lasts only as long as the action persists. As soon as the action ceases the reaction also ceases.
2. Action and reaction act on two different bodies, never on the same body.

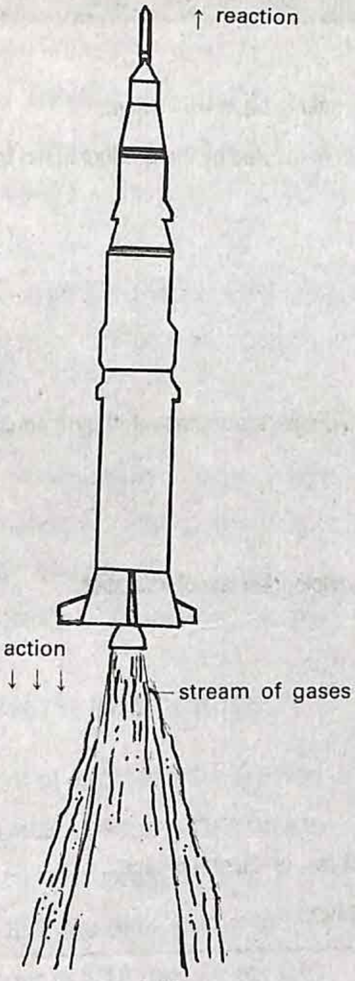


Fig. 2.19

2.10 Streamlining

When we walk through a pool of water we experience a resistance to our motion just as objects moving in air experience a resistance to their motion. This shows that there is a frictional force in liquids. This frictional force is usually referred to as the *viscous drag* of the liquid or fluid.

When objects that move in air or water are designed in such a way that they experience the least amount of viscous drag it is called *streamlining*.

Activity 17: *Make a list of action and reaction forces. Can you add more examples to the list ?*

Activity 18: *Take a few objects of various shapes (preferably lighter objects) and gently move them through some water. Which shape offers most resistance to the motion ? Which shape offers least resistance to the motion ?*

Basic concepts

1. When a body is acted upon by forces which keep it at rest it is said to be in equilibrium.
2. The turning effect of a force is the moment of the force which is measured by the product of the force and the perpendicular distance of the force from the fulcrum.
3. Forces are recognised by their effects.
4. Speed $= \frac{\text{distance travelled}}{\text{time taken}}$ ms^{-1}
5. Velocity $= \frac{\text{displacement}}{\text{time}}$ ms^{-1}
6. Scalars are completely represented by magnitude whereas Vectors are represented by magnitude and direction.
7. Acceleration $= \frac{\text{change in velocity}}{\text{time taken}}$ ms^{-2}
8. The resultant of two velocities may be calculated from the parallelogram law of velocities.
9. The three equations of motion are:

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

10. Inertia is the inability of a body to change by itself its state of rest or uniform motion.
11. The product of mass and velocity of a body gives its momentum.

Some investigatory projects/ activities

I. Draw three objects that move in air or water which are streamlined.

REVISION

I. Fill in the blanks :

1. The turning effect of a force is known as ____________________ of the force.
2. The point about which a body rotates is the______________.
3. The moment of force is the product of the ________________ and ________________
4. According to the law of moments ________________ moments = ________________ moments.
5. Quantities which possess only magnitude are ____________ .

6. Quantities which possess both magnitude and direction are ______________.
7. The rate at which a body changes its position is called ________________.
8. The rate of displacement of a body is called __________.
9. When the velocity of a body increases with time it is called ______________.
10. When the velocity of a body decreases with time it is called ______________.
11. One kilometre per hour equals _____________m/s.
12. Quantities which possess both magnitude and direction are called ________________.
13. If two cars move in the same direction, with equal velocities, side by side, the velocity of any one car relative to the other is _____________.
14. Galileo showed that all bodies fall with the same __________.
15. Momentum is measured by the product of ______and _______.
16. The force acting on a body of mass 5 kg to give it an acceleration of 2 m/s^2 is _________.
17. Every action has an _______and _______ reaction.
18. Angular velocity is the angle described by the _________ in one second.

II. *State whether true or false :*

1. The moment of a force is the product of mass and distance from the fulcrum.
2. A scalar quantity has only magnitude.
3. Time is a vector quantity.
4. Velocity is the rate of displacement of a body.
5. 1 km per hour is 5/18 metres per sec.
6. If the velocity of a body changes by 50 ms^{-1} in 5 secs. its acceleration is 10 ms^{-2}.
7. The acceleration due to gravity is a universal constant.
8. The value of 1 radian is equal to 1 degree.
9. If there were no gravitational force, planets would not revolve around the sun.
10. Momentum does not depend on mass.
11. The mass of an object is the same on a satellite as on earth.
12. The acceleration due to gravity is the same everywhere.
13. The momentum of a car and lorry moving with the same velocity is the same.
14. The unit of momentum is Nm.
15. The momentum of a body of mass 50 kg moving with a velocity of 10 ms^{-1} is 500 kg ms^{-1}.

III. Choose the correct answer.

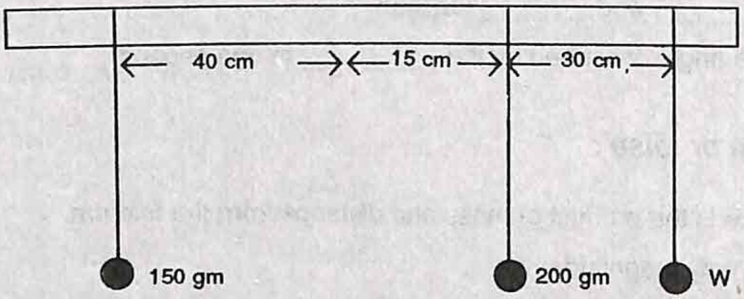
1. The weight of a body is (a) greatest at the equator. (b) greatest at the poles. (c) remains the same throughout.
2. The moment of a force depends (a) only on its mass. (b) on mass and velocity. (c) on force and distance. (d) only on the force.
3. The momentum of a body depends (a) only on its mass. (b) only on its velocity. (c) on neither mass nor velocity. (d) on mass and velocity.
4. kg m/sec^2 is the unit of (a) momentum. (b) force. (c) moment of a force. (d) velocity.

V. Answer the following questions briefly :

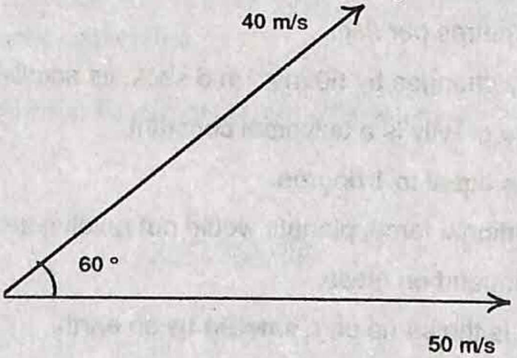
1. Define the following quantities and give their units in the SI system.

   (i) speed (ii) velocity (iii) displacement (iv) acceleration (v) retardation.

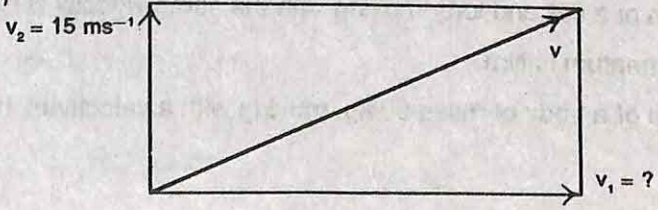
2. Find the value of *W* in the following diagram :



3. Find the magnitude and direction of the resultant velocity in the following.



4. Find the value of v_1 and v



5. The data given below shows the speed of a car at intervals of 1 second. Plot the speed versus time graph, and use it to answer the following questions :

(a) How fast is the car going at 2.8 sec.? At 4.5 sec ?

(b) How far did the car travel between the two instants in part (a) ?

Time (*s*)	0.0	1.0	2.0	3.0	4.5	5.0	6.0
Speed (m/s)	10.0	12.4	14.8	17.2	19.6	22.0	24.4

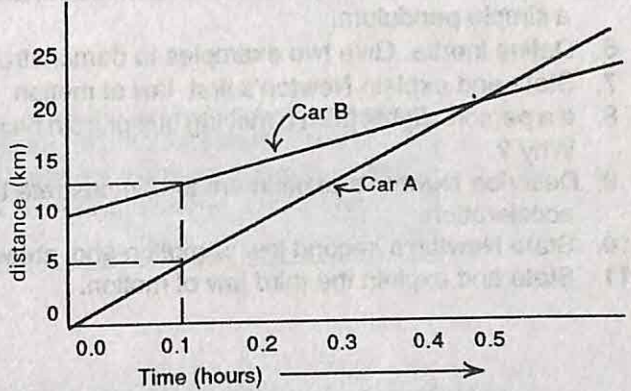
6. The following time-distance graph is plotted for two cars *A* and *B*. Study the graph carefully and answer the questions below:

(a) Which of the two cars is moving faster ?

(b) Which car started ahead of the other ?

(c) After what interval of time does *A* overtake *B* ?

(d) How many km does *A* travel before it overtakes *B* ?

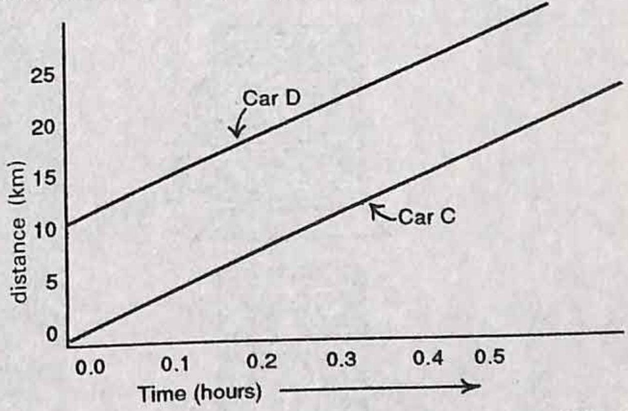


7. The following graph shows the motion of two cars *C* and *D*. Study the graph and answer the questions below :

a. Which car is moving faster ?

b. Which car starts ahead of the other ?

c. Will one of them overtake the other ? If so when ?



8. A motor car moving with a velocity of 24 ms^{-1} is uniformly accelerated at 2 ms^{-2} for 20 secs. What is its velocity ?

9. Find the force required to give a mass of $3\frac{1}{2}$ kg an acceleration of 7 ms^{-2}.

10. Find the acceleration produced by a force of 45 newtons on a mass of 15 kg.

11. A car starts from rest and is accelerated uniformly at the rate of 2 ms^{-2} for 5 seconds. What is its velocity at the end of this interval of time ?

12. The brakes are applied to a car travelling at 39 ms^{-1} and it comes to rest in 6 seconds. Find its retardation.

13. A stone is dropped from a height of 10 m. Find the time taken for it to reach the ground.

V. Answer the following questions:

1. State and explain the law of moments.
2. How will you verify the law of moments in the laboratory ?
3. Derive the three equations of motion.
4. How are the equations of motion altered for motion under gravity ?
5. Describe briefly how you would determine the acceleration due to gravity in the laboratory using a simple pendulum.
6. Define inertia. Give two examples to demonstrate it.
7. State and explain Newton's first law of motion.
8. If a person alights from a moving bus or train he runs for a short distance before coming to rest. Why ?
9. Describe Newton's experiment to demonstrate that all bodies fall with the same velocity and acceleration.
10. State Newton's second law of motion and show that $F \propto ma$.
11. State and explain the third law of motion.

3. Hydrostatics

Properties of liquids - liquid pressure - principle of balancing columns - atmospheric pressure - pressure in gases - application of fluid pressure - barometer - hydraulic press - jack - brake - Archimedes' principle - relative density

3.1 Properties of liquids

Activity 1: ***The following diagrams are related to different properties of liquids at rest. Recall what you have learnt earlier and mention the property each diagram depicts.***

(1) ______________________

____

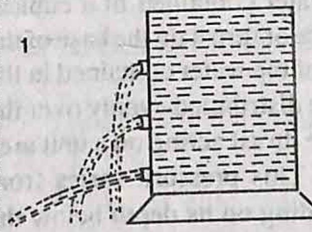
(2) ______________________

____

(30 ______________________

____

1



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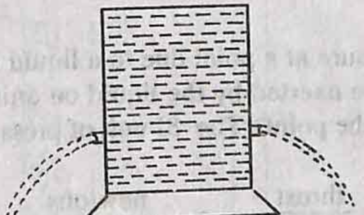

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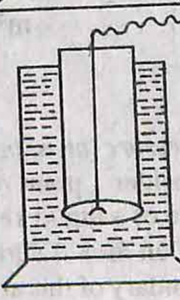
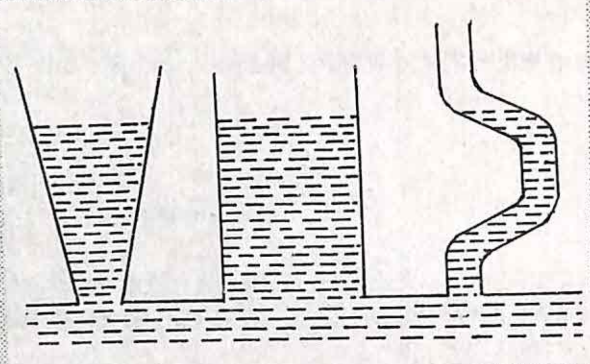


(4) ______________________________

____

____



3.2 Liquid pressure

The weight of a block of iron resting on a table acts downwards and presses the surface in contact with the table.

This pressing force acting perpendicular to the surface is distributed over the entire area of the surface and is termed *thrust*, i.e., thrust is the force acting normal to a surface. In the SI system thrust is measured in newtons.

Consider some water contained in a cubical vessel. The total force or thrust on the base of the vessel is the weight of the water contained in the vessel. This thrust is distributed evenly over the area of the base. The thrust acting on a unit area is called *pressure*. This pressure varies from point to point depending on its depth below the surface.

The pressure at a point due to a liquid is the normal force exerted by the liquid on unit area containing the point. The SI unit of pressure is a *pascal*.

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} = \frac{\text{newtons}}{\text{m}^2}$$

$$1 \text{ pascal} = 1 \text{n m}^{-2}$$

Calculating the pressure at a point within a liquid at rest : Consider a point o at a depth h from the free surface of a liquid kept in a vessel (Fig. 3.1). Describe an area a surrounding this point. From the boundary of this area draw lines vertically to meet the free surface of the liquid. Since the area of the imaginary cylinder is very small the thrust on this area may be taken to be uniform. The thrust on this area is the weight of the column of liquid above area a.

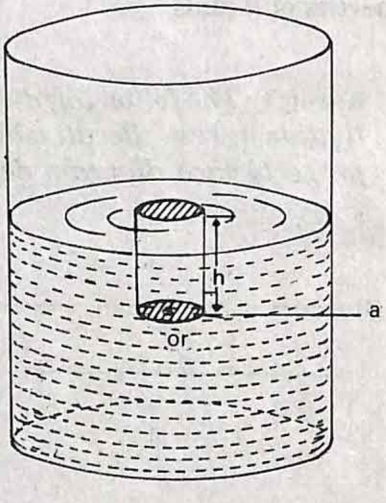


Fig. 3.1 Pressure at a point in a liquid

$$\begin{aligned} \text{Thrust} &= mg \\ &= \text{volume} \times \text{density} \times g \\ &= ah \times d \times g \\ &= ahdg \text{ newtons} \end{aligned}$$

$$\text{We know that pressure} = \frac{\text{thrust}}{\text{area}} = \frac{ahdg}{a}$$

$$\therefore \underline{P} = hdg \text{ pascals}$$

Example : *Calculate the pressure at a point of depth 10 cm in a liquid (contained in a vessel). The density of the liquid is 1500* kgm^{-3}.

h = 10 cm = 0.1 m
d = 1500 kgm^{-3}
g = 9.8 ms^{-2}
p = hdg
= 0.1 x 1500 x 9.8
= 1470 pascals

PRINCIPLE OF BALANCING COLUMNS

When water is poured into tubes of different shapes communicating with each other, the water stands at the same vertical height in all the tubes, i.e. water finds its own level. In other words *the pressure must be the same at all points at the same horizontal level.* So the pressure at B = pressure at D. The apparatus as shown in Fig. 3.2 is referred to as an U-tube apparatus or a balancing column of liquid.

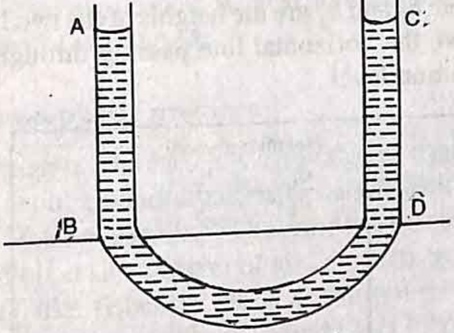


Fig. 3.2 A U-tube apparatus

Relative Density : The density of a substance has been defined as its mass per unit volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}} \ kgm^{-3}$$

The relative density of a substance is defined as the ratio of the density of a substance to the density of water.

$$\text{relative density} = \frac{\text{density of substance}}{\text{density of water}}$$

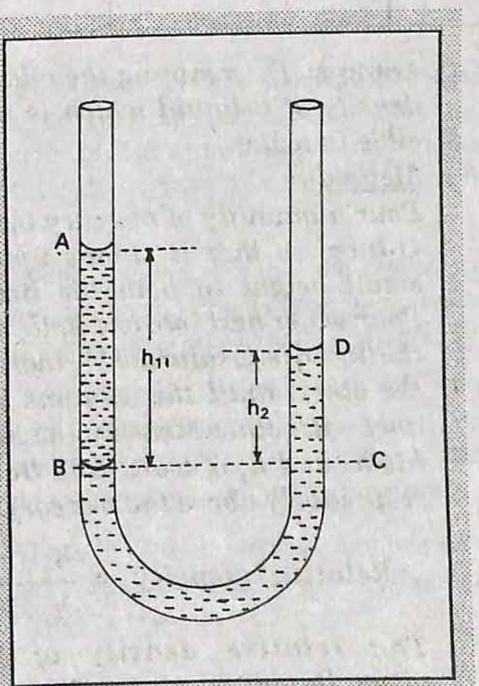
$$\text{hence, r.d.} = \frac{\text{mass of substance}}{\text{mass of an equal volume of water}}$$

Since relative density is the ratio of two masses, it has no units. It is just a number which tells us how much heavier than water a particular substance is.

Activity 2: U-tube method

Aim: Determining the relative density of a liquid immiscible in water, e.g., paraffin.

Method: Fix a U-tube to a stand. Pour water through one limb and the liquid through the other limb till one of them partly fills both the limbs. In the figure, AB = h_1*, is the height of the liquid of density* d_1 *above the common level at B. Place a ruler horizontally along BC through the common level at B. Using a half-metre scale measure the heights* h_1 *and* h_2 *above the ruler. Let CD =* h_2 *be the height of water of density* d_2*, above the common level C in the other limb.*



Since B and C lie in the same horizontal line, the pressures at these points are equal, i.e. if P is the atmospheric pressure, then,

$$\begin{aligned} \text{Pressure at } B &= \text{Pressure at } C \\ P + h_1 d_1 g &= P + h_2 d_2 g \\ \text{or, } h_1 d_1 g &= h_2 d_2 g \\ \text{or, } h_1 d_1 &= h_2 d_2 \end{aligned}$$

$$\text{or} \quad \frac{d_1}{d_2} = \frac{h_2}{h_1}$$

By definition $\frac{d_1}{d_2}$ is the relative density of the substance. Hence,

$$\text{Relative density} = \frac{h_2}{h_1}$$

Tabulate your readings as shown below. Calculate the value of h_2/h_1 in each case and enter the value obtained in the last column. Find the average h_2/h_1. This gives the relative density of the liquid.

The densities of two immiscible liquids can be compared by the above method. In this case, the ratio of the densities

$$\frac{d_1}{d_2} = \frac{h_2}{h_1}$$

where h_1 and h_2 are the heights of the two liquids above the horizontal line passing through their common level.

Serial Number	*Height of water column* h_2	*Height of liquid column* h_1	*Relative density* $\frac{d_1}{d_2} = \frac{h_2}{h_1}$
1			
2			
3			

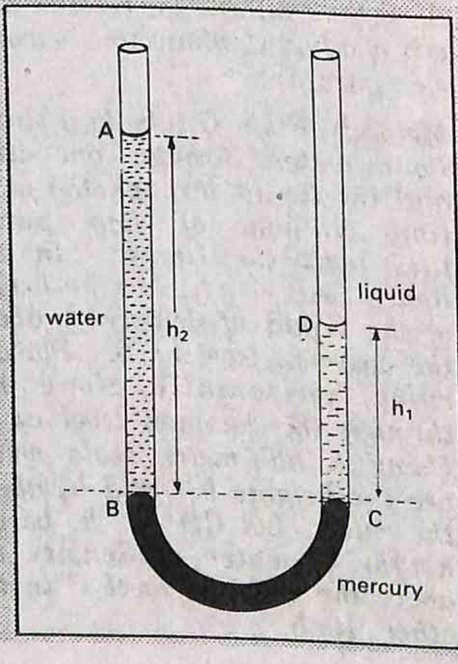
Activity 3: ***Determining the relative density of a liquid which is miscible in water.***

Method :

Pour a quantity of mercury into a U-tube, so that it stands upto a small height in both the limbs. Pour water next into one limb, and the liquid (e.g. saturated brine) into the other, until the columns balance each other. Measure the heights h_2 and h_1 of water and liquid respectively above the mercury.

$$\textit{Relative density} = \frac{h_2}{h_1}$$

The relative density of the given liquid is =



Since B and C lie on the same horizontal line, the pressure at, B and C are equal. If the atmospheric pressure is P, then

$$\begin{aligned}
\text{Pressure at } B &= \text{Pressure at } C \\
P + h_1 d_1 g &= P + h_2 d_2 g \\
h_1 d_1 &= h_2 d_2
\end{aligned}$$

$$\text{or } \frac{d_2}{d_1} = \frac{h_1}{h_2} \quad \text{and} \quad \frac{d_1}{d_2} = \frac{h_2}{h_1}$$

$$\text{Relative density} = \frac{d_1}{d_2} = \frac{h_2}{h_1}$$

The above expression is used to compare the densities of two liquids.

3.3 Atmospheric pressure

The surface of the earth is surrounded by a jacket of air about a hundred miles in height which is termed the *atmosphere*. The atmosphere can be looked upon as an ocean of air in which we are moving like fishes in the sea. Although this atmosphere is invisible, we easily feel its presence all round us. Wind, which can be heard and felt, is merely air in motion. Air, no doubt, is much lighter than solids and liquids and to the ordinary man it may appear to possess no weight. But air also is a material substance and has weight. The weight of a definite volume of air and hence the density of air can be determined quantitatively. Since air has weight, it exerts a pressure on the surface. It is this pressure exerted by the weight of the air which is termed the atmospheric pressure.

Atmospheric pressure is constantly used for forecasting changes in weather. If the air contains much water vapour, its pressure is less (for water vapour is lighter than air) and the height of mercury in a barometer is less. A low reading, therefore, generally shows that rain is near.

More than the actual pressure on any particular day, it is important to see how pressure changes. A falling barometer means rain and a rising barometer means better weather.

It is not, however, possible to forecast the weather by reading the barometer at one place. Every day the pressure is measured at different places and sent to a central station. The readings are all plotted on a map and places of equal pressure are joined by lines, called *isobars*. The meteorologist compares the maps drawn on successive days and finds out the regions of the lowest pressure and the direction in which this region is moving. Then he asks himself the question, "*What will the picture be tomorrow?*" He sees perhaps that an area of low pressure is moving towards a particular part of the country. He next publishes his forecast in the newspapers and announces it on the radio.

3.4 Pressure in gases

Unlike solids and liquids, gases do not occupy a definite volume. A gas always occupies the whole of the available space of the vessel which contains it. If the volume of the vessel is increased, the gas still fills the whole vessel, but the pressure the gas exerts on its walls is reduced. Conversely, if the volume is reduced, the pressure is increased.

BOYLE'S LAW

In 1662, Robert Boyle investigated the relationship between the volume of a given mass of gas and the pressure to which it is subjected and his results are expressed in the law called Boyle's law.

Boyle's law states that the *temperature remaining constant, the volume of a given mass of gas varies inversely with its pressure.*

For example, when a man sits on an air-cushion, if its volume becomes 1/3 of its initial volume, then the pressure of the air inside becomes three times the initial pressure.

Thus if V represents the volume of a given mass of a gas whose pressure is P, then according to Boyle's law

$$\text{volume} \propto \frac{1}{\text{pressure}}$$

Activity 4: *Try to understand how the following example has been worked out and then work it out by yourself.*

or $V \propto \frac{1}{P}$

or PV = constant

So if V_1 and V_2 be volumes of a given mass of gas, at pressures P_1 and P_2, then

$P_1V_1 = P_2V_2$ since PV is a constant.

Example :*The volume of air enclosed in a Boyle's law tube is 50 cm³ at 760 mm Hg. Find the pressure at which the volume will be 76 cm³.*

P_1 = 760 mm of Hg. P_2 = ?

V_1 = 50 cm³ V_2 = 76 cm³

According to Boyle's law, $P_1V_1 = P_2V_2$

$760 \times 50 = P_2 \times 76$

$\therefore P_2$ = 500 mm of Hg.

MANOMETERS

Manometers are instruments used for measuring the pressure of an enclosed volume of gas. Ordinary liquid manometers are used to measure pressures which are not very different from the atmospheric pressure.

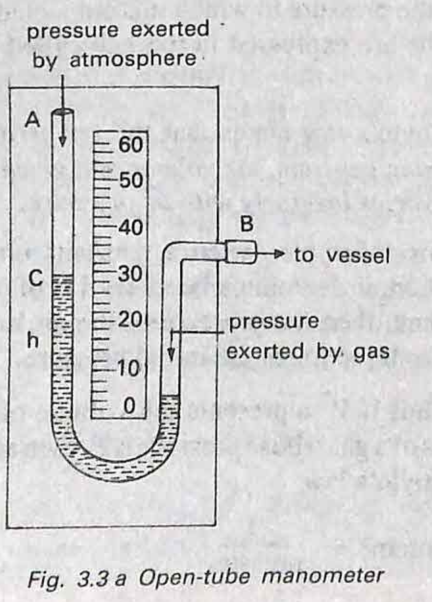


Fig. 3.3 a Open-tube manometer

Open-tube manometer : This consists of a U-tube open at both ends, which contains a liquid. If the pressure to be measured is slightly higher or lower than the atmospheric pressure, then oil is used as the liquid. If the pressure difference to the atmosphere is relatively large, then mercury is used. The end B of the tube is connected with the vessel containing the gas, the pressure of which is to be measured, while the end A is open to the atmosphere.

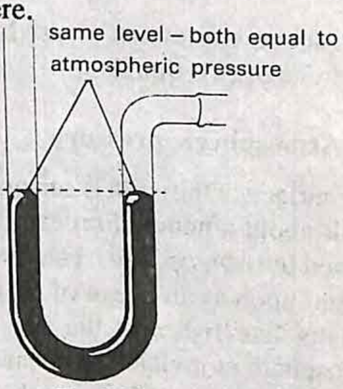


Fig. 3.3 b

a. If the pressure inside the vessel is equal to the atmospheric pressure, then the level of liquid in both the limbs will be the same. If P_0 be the atmospheric pressure, then the pressure inside the vessel is also P_0.

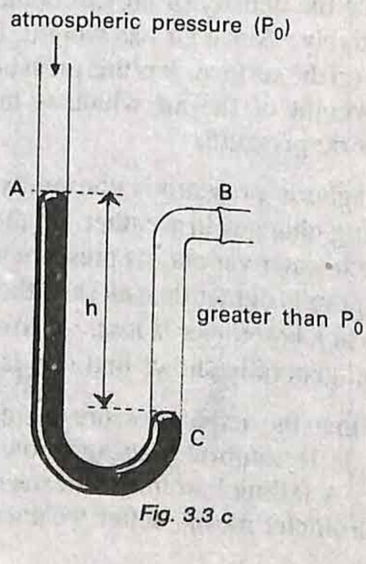


Fig. 3.3 c

b. If the pressure to be measured is greater than the atmospheric pressure, then the liquid is pushed up in the open limb A. The difference of levels of the liquid in the two limbs is noted. Let it be h. Hence, the pressure in B is greater than the pressure in A, by the pressure exerted by the column of liquid of height h (Fig. 3.3c).

If d is the density of the liquid, then the pressure exerted by the column of liquid $= hdg$.

The pressure of the gas to be measured (P) is greater than the atmospheric pressure (P_0) by hdg.

or, $P = P_0 + hdg$.

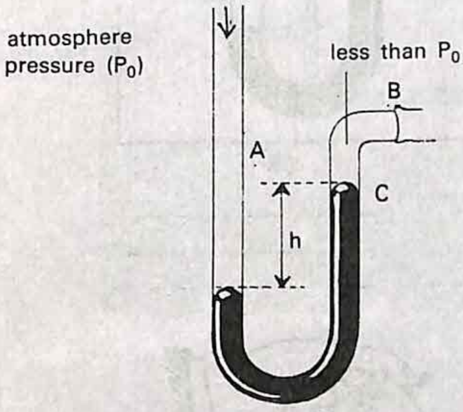


Fig. 3.3 d

c. If the pressure to be measured is less than the atmospheric pressure, the atmospheric pressure acting on the liquid in A pushes it up in the limb B of the manometer. The pressure in the vessel is now hdg less than the atmospheric pressure, or, $P = P_0 - hdg$.

Closed-tube manometer : If the pressure of the gas is much less than atmospheric pressure (near vacuum), a closed U-tube manometer may conveniently be used. One limb of this manometer is closed while the other is open. Mercury completely fills the closed limb, but there is a small amount in the open limb. The open end B is connected to the vessel containing the gas, the pressure of which is to be measured. When this pressure is very low, the mercury column in the closed tube descends. If h is the difference of levels in the two limbs, then the pressure P of the gas is

$$P = hdg.$$

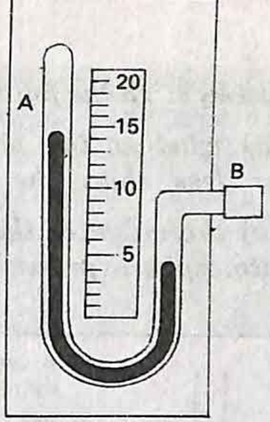


Fig. 3.4 Closed-tube manometer

The closed tube manometer can also be used to measure very high pressures. For this, the closed tube contains some dry air above the mercury column. When the vessel containing the gas whose pressure is to be measured is connected to the open end B, the mercury in tube A is pushed up, compressing the air above the mercury. By applying Boyle's law to the pressure and volume of the gas before and after connecting the vessel, the pressure can be calculated. The scale along the closed limb is graduated to measure the pressure in atmospheres.

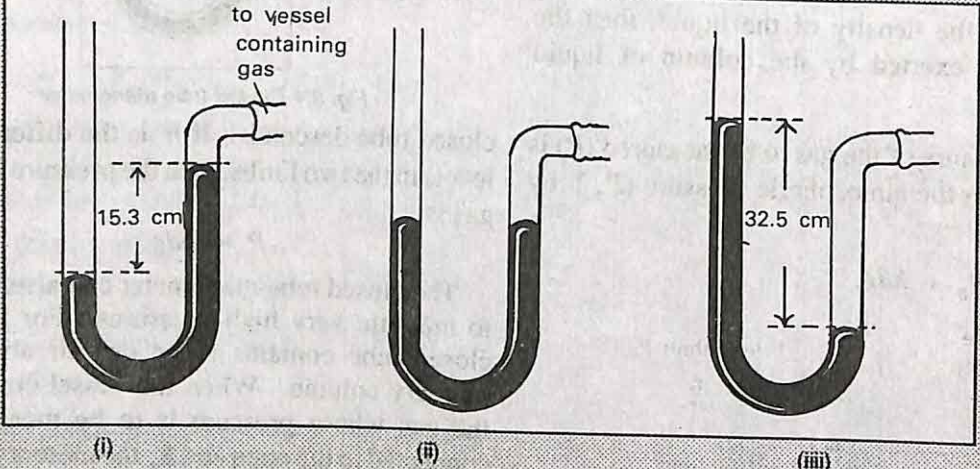
Calculating pressure

Before connecting to the gas supply,
length of the air column $l_1 = l$
difference in mercury level $= h$
pressure $P_1 = H + h$ (the atmospheric pressure $= H$)
After connecting to the gas supply whose pressure P is to be found
length of air column $= l_1$
difference in mercury level $= h_1$
pressure $= P + h_1$
Applying Boyle's law,
$P_1 l_1 = P_2 l_2$
($v \propto 1$ in a uniform tube)
$(H + h) l = (P + h_1) l_1$
From this P can be calculated.

Activity 5: *In the following figures of open tube manometers, decide:*

(a) whether the pressure of the gas is equal to, greater than or less than the atmospheric pressure.

(b) the value of the pressure of the gas in cm of mercury if the atmospheric pressure is 76 cm of Hg.



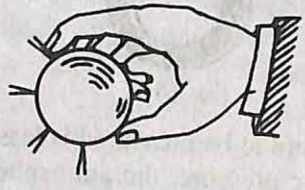
(a) ____________ ____________ ____________

(b) ____________ ____________ ____________

(c) ____________ ____________ ____________

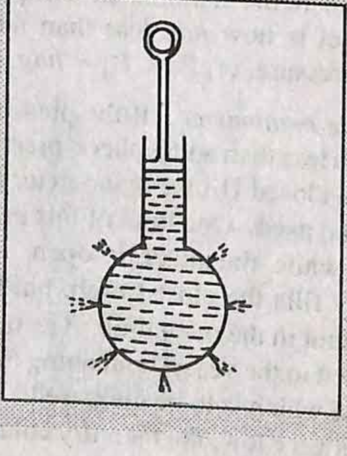
3.5 Applications of fluid pressure

Pascal's law: This law states that an increase of pressure applied at any point in a liquid at rest is transmitted equally in all directions to every other point in the liquid.



Activity 6: *(1) Take an India-rubber ball and make a number of holes in it with a pin. Fill it with water and compress it with the hand. The water is forced out equally through the openings.*

(2) A syringe with a perforated spherical bulb at its ends is filled with water. When the piston is pushed inwards, water is found to spurt out radially with equal force as shown in the figure. What does this show?



THE BRAMAH PRESS OR THE HYDRAULIC PRESS

The principle of transmissibility of fluid pressure finds its most useful application in the hydraulic press (Fig. 3.6).

Suppose we have two cylindrical vessels connected together and provided with pistons closely fitting into them. Let the area of the pistons be in the ratio of 10:1. Let the small piston *p* be forced down with a weight of 1 kg; the large piston *P*

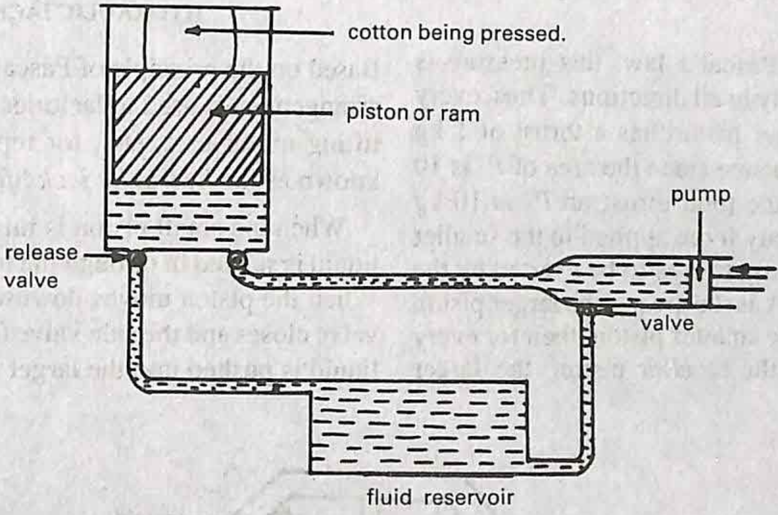


Fig. 3.5 Hydraulic press

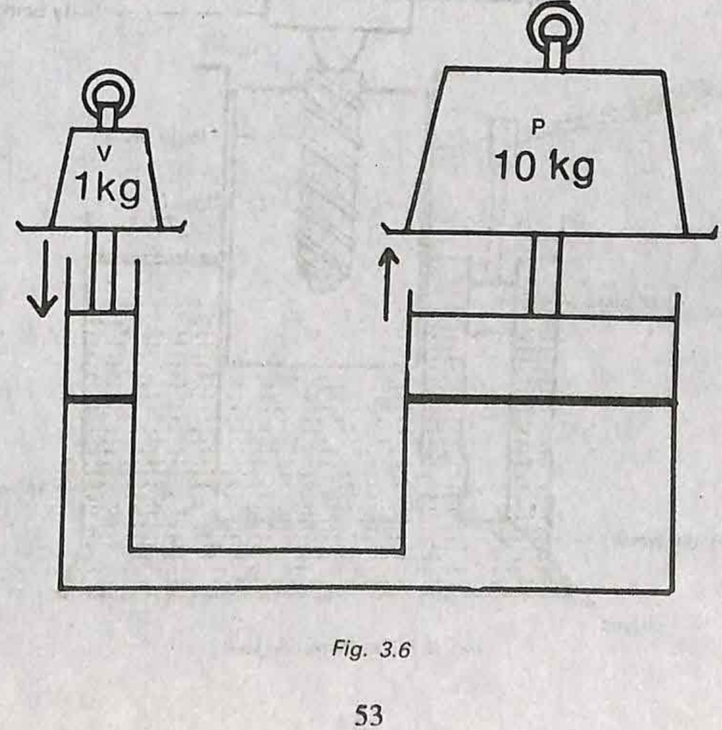


Fig. 3.6

will rise with a force of 10 kg weight (Fig. 3.6). The larger piston can thus be made to raise a weight of 10 kg by placing a weight of 1 kg on the smaller piston. This result which appears strange is termed the *hydrostatic paradox,* but the paradox is easily explained.

Let the area of the smaller piston be 1 sq. m. The pressure applied on the smaller piston is 1 kg per sq. m.

According to Pascal's law, this pressure is transmitted equally in all directions. Thus, every sq. m of the larger piston has a thrust of 1 kg acting on it and hence since the area of P is 10 times that of p, the total thrust on P is 10 kg weight. Hence, any force applied to the smaller piston causes a larger force to be exerted by the larger piston. If A is the area of the larger piston and 'a' that of the smaller piston, then for every kgf applied on the smaller piston, the larger piston will rise with a force $\frac{A}{a}$kgf of kg weight. If A is 100 times greater than 'a' then $\frac{A}{a} = 100$, and the thrust is multiplied 100 times.

The principle is used to compress paper or cotton bales, and pressing metals to desired shapes, etc.

HYDRAULIC JACK

Based on the principle of Pascal's law, a lifting arrangement is used in factories and garages for lifting motor cars, etc., for repair work. It is known as the *hydraulic jack lift*.

When the small piston is raised upwards the liquid is sucked in through the bottom valve (6). When the piston moves downward, the bottom valve closes and the side valve (6) opens and the liquid is pushed into the larger cylinder.

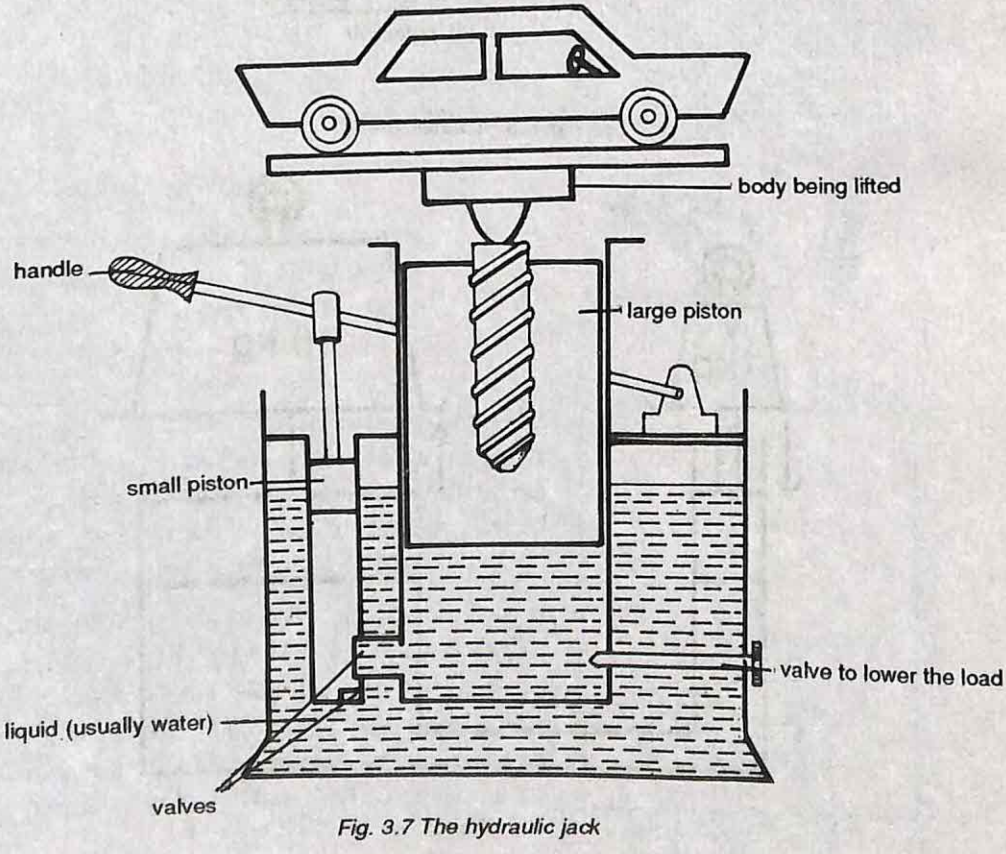
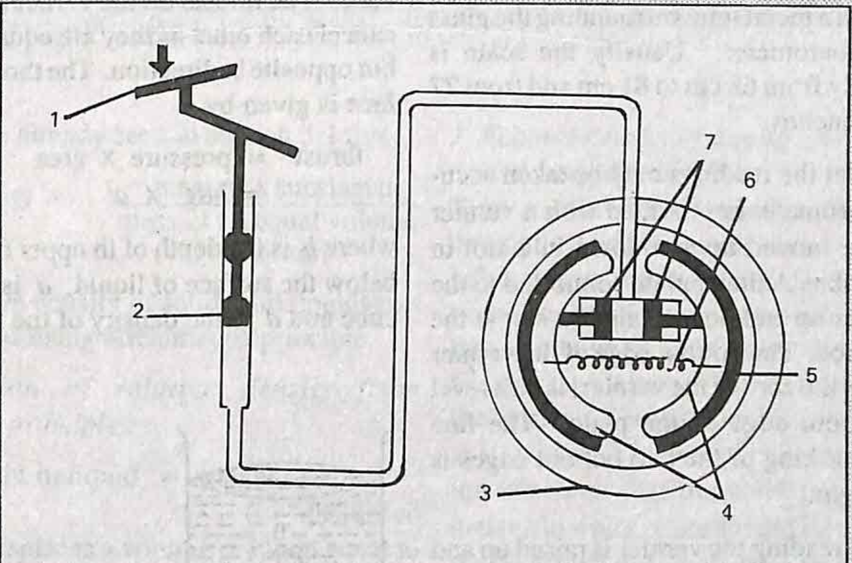


Fig. 3.7 The hydraulic jack

Activity 7: *Given below is the schematic diagram of the hydraulic brake system. Looking at the diagram, describe in a few words the principle of operation of the brake.*

The cylinders and pipes are filled with a special liquid called the brake fluid.



1. brake pedal
2. cylinder with piston
3. brake drum, coaxial with the rotating wheel
4. brake shoes
5. brake shoe lining
6. spring
7. piston in a cylinder

THE FORTIN'S BAROMETER

In the ordinary type of barometer, it is necessary to take the reading of the mercury level in the cistern. The difference between the levels is the barometric pressure. The measurements in the case of this type of barometer is a bit cumbersome, time consuming and not very accurate.

In the Fortin's barometer (Fig. 3.8) only one reading, i.e., the reading of the level of the mercury in the tube alone need be read and this can be done very accurately.

Fortin's barometer consists of a vertical glass tube dipping in a cistern containing mercury. The upper part of the cistern is of glass, through which the surface of the mercury can be seen. The cistern is provided with a leather bottom

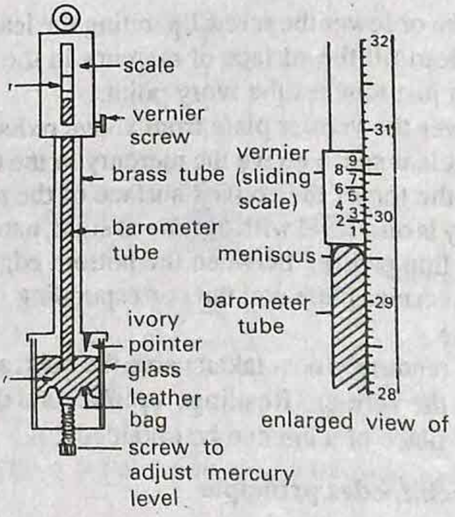


Fig. 3.8 Fortin's barometer

which can be raised or lowered by a screw. A small ivory pin is fixed to the top of the cistern. The special feature of this barometer is that the surface of the mercury in the cistern can be adjusted by raising or lowering the screw so that it touches the ivory point. This ivory point exactly marks the zero of the vertical scale which is engraved on a metal tube surrounding the glass tube of the barometer. Usually the scale is graduated only from 68 cm to 81 cm and from 27 inches to 32 inches.

In order that the readings may be taken accurately, the barometer is provided with a vernier which can be moved up and down in a slot in front of the tube. A metal plate connected to the vernier moves up and down a similar slot at the back of the tube. The bottom edge of the vernier (which marks the zero of the vernier) is on a level with the bottom edge of the plate. The line joining the marking of the two bottom edges is the line of sight.

In taking a reading the vernier is raised up and down, till the top of the convex surface of the mercury is on a level with the line of sight. This avoids any parallax error in the reading.

To take a reading :

1. Raise or lower the screw operating the leather bottom till the surface of mercury in the cistern just touches the ivory point.
2. Lower the vernier plate from above reducing the clear space above the mercury in the tube till the top of the convex surface of the mercury is on a level with the line of sight, namely the line passing between the bottom edge of the vernier plate and the corresponding back plate.
3. The reading is now taken using the main scale and the vernier. Readings upto second decimal place of a cm can be obtained.

3.6 Archimedes principle

Archimedes principle states: *When a body is wholly or partially immersed in a liquid, it appears to lose some weight. The apparent loss of weight is equal to the weight of liquid displaced by it.*

ABCDEFGH is a cube immersed in a liquid with the faces *ABCD* and *EFGH* horizontal. The liquid exerts thrust on all the six faces of the cube. The thrusts on the vertical opposite sides cancel each other as they are equal in magnitude but opposite in direction. The thrust on the upper face is given by

$$\begin{aligned}\text{thrust} &= \text{pressure} \times \text{area}\\ &= hdg \times a^2\end{aligned}$$

where h is the depth of th upper face of the cube below the surface of liquid, a is the side of the cube and d is the density of the liquid.

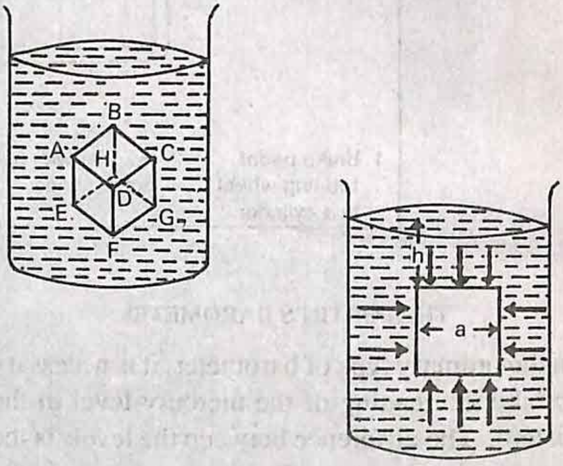


Fig 3.9

The thrust on the lower surface of the cube is given by

$$\begin{aligned}\text{thrust} &= \text{pressure} \times \text{area (acting upwards)}\\ &= (h+a)\,dg \times a^2\end{aligned}$$

$\therefore$ the resultant thrust on the cube is

$$\begin{aligned}&(h+a)\,dga^2 - hdga^2\\ &= a^3dg\end{aligned}$$

Since a^3 is the volume of the cube, $a^3 \times d$ gives the mass of the volume of liquid displaced by the cube.

$\therefore$ thrust $= mg$

Thrust = weight of displaced liquid

Since this thrust acts upwards it is called *upthrust* or *buoyancy* of the liquid. It is this upthrust or buoyancy which causes the body to appear to lose weight.

Activity 8: *List some applications of Archimedes' principle in daily life.*

3.7 We have already seen in section 3.2 that

$$\text{relative density} = \frac{\text{mass of a substance}}{\text{mass of an equal volume of water.}}$$

The relative density of solids and liquids can be determined using Archimedes' principle.

Determination of relative density from Archimedes' principle :

Loss of weight in liquid = weight of liquid displaced

But a body displaces a volume of liquid equal to its own volume.

$\therefore$ Loss of weight of a body in a liquid = weight of its own volume of liquid

So if a body is completely immersed in water,

loss of weight of body in water = weight of an equal volume of water .... (1)

Now, from our definition of relative density

$$\text{relative density} = \frac{\text{mass of substance}}{\text{mass of an equal volume of water}}$$

and from (1)

$$\text{relative density} = \frac{\text{mass of substance}}{\text{loss of weight in water}}$$

$$\therefore \text{relative density} = \frac{\text{weight of a substance in air}}{\text{loss of weight in water}} \quad \text{... (2)}$$

Hence, Archimedes' principle may be used to determine the relative density of a substance.

1. Relative density of a solid heavier than water and insoluble in water.

Take a solid whose relative density is to be determined and suspend it from the hook of the left scalepan of a physical balance by means of a very fine thread. Weigh the susbtance in air. Let this weight be W_1. To weigh the solid in water, a hydrostatic bench is placed over the left pan of the balance. The pan should not touch the bridge as it swings. A beaker of water is then placed on the bench so that the solid is completely immersed in water. Care should be taken to see that the body does not touch the sides or bottom of the beaker. There should be no air bubbles sticking to the solid.

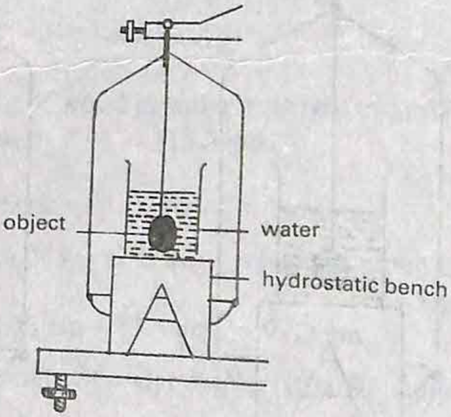


Fig. 3.10 Relative density : solid heavier than liquid

Find the weight of the solid in water. Let this be W_2.

Weight of the solid in air $= W_1$

Weight of the solid in water $= W_2$

Loss of weight in water $= W_1 - W_2$

From (2)

$$\text{relative density} = \frac{\text{weight in air}}{\text{loss of weight in water}}$$

$$\text{relative density} = \frac{W_1}{W_1 - W_2}$$

2. Relative density of a solid lighter than and insoluble in water, e.g. cork.

Since the substance is lighter than water, it will float in water. Therefore, to keep it in water another heavy solid known as a sinker is used. For example, a piece of iron or lead may be used as a sinker.

The procedure is illustrated in Fig. 3.14. First tie a thread to the sinker, immerse it in water and determine its weight in water. Let this be W_1. Then the cork is attached to the same thread in such a way that it is above the water surface, so that its weight in air can be determined. Let the weight of cork in air + sinker in water now obtained be W_2. Next tie the cork near the sinker so that both are totally immersed in water, and find their combined weight in water. Let it be, W_3. Then,

weight of cork in air $= W_2 - W_1$

weight of cork in water $= W_3 - W_1$

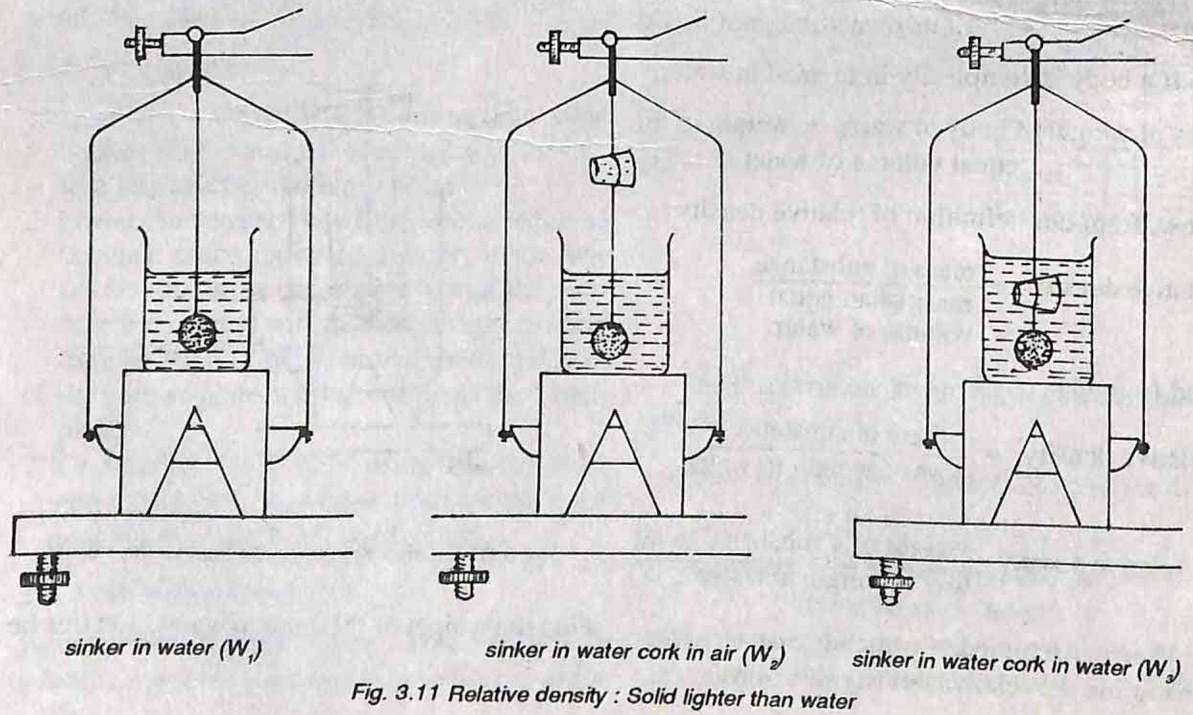
loss of weight in water $=$ weight in air – weight in water

$$(W_2 - W_1) - (W_3 - W_1)$$

$\therefore$ loss of weight in water $= W_2 — W_3$

$$\text{relative density} = \frac{\text{weight in air}}{\text{weight in water}}$$

$$\text{relative density} = \frac{W_2 - W_1}{W_2 - W_3}$$



sinker in water (W_1) sinker in water cork in air (W_2) sinker in water cork in water (W_3)

Fig. 3.11 Relative density : Solid lighter than water

3. Relative density of a liquid

A solid heavier than the given liquid and water, is taken. The solid should be insoluble in water and in the liquid. Usually a glass stopper or a metal bob is taken.

Suspend the solid by a thread and find its weight in air, water and liquid as in the previous experiments. Let the

weight of the solid in air $= W_1$

weight of the solid in water $= W_2$

weight of the solid in liquid $= W_3$

By Archimedes' principle,

loss of weight in water = weight of water displaced

loss of weight in liquid = weight of liquid displaced

Since the same solid is immersed in both liquid and water, the volume of liquid and water displaced are the same. By definition,

$$\text{relative density} = \frac{\text{weight of any volume of a substance}}{\text{weight of an equal volume of water}}$$

$$\text{relative density} = \frac{\text{weight of liquid displaced}}{\text{weight of water displaced}}$$

$$\text{or relative density} = \frac{\text{loss of weight in liquid}}{\text{loss of weight in water}}$$

$$\frac{W_1 - W_3}{W_1 - W_2}.$$

Activity 9: *Follow the steps given in experiments 1, 2 and 3 to find out the relative densities of (i) a metal bob, (ii) a rubber stopper, and (iii) kerosene oil.*

Activity 10: *Work out the following problems and then check the solutions and the steps used.*

Example 1 A solid weighs 27.85 gm in air and 16.45 gm in water. What is its relative density ?

weight of solid in air = 27.85 gm

weight of solid in water = 16.45 gm

apparent loss of weight = 11.40 gm

$$\text{relative density} = \frac{\text{weight in air}}{\text{loss of weight in water}}$$

$$= \frac{27.85 \text{ gm}}{11.40 \text{ gm}}$$

$$= 2.44$$

Example 2

A piece of wood weighs 74 gm in air. A lead sinker which weighs 32 gm in water is attached to the wood to sink it. If the total weight in water is 13.5 gm find the relative density of wood.

weight of wood in air + weight of sinker in water

= 74 gm + 32 gm

= 106 gm

weight of wood in water + weight of sinker in water = 13.5 gm

Subtracting,

weight of wood in air − weight of wood in water

= 106 gm − 13.5 gm = 92.5 gm

i.e., weight of water displaced = 92.5 gm

$$\text{relative density} = \frac{\text{weight in air}}{\text{loss of weight in water}} = \frac{74 \text{ gm}}{92.5 \text{ gm}}$$

$$= 0.8$$

Basic concepts

1. Pressure at a point within a liquid at rest = hdg pascals.
2. According to the principle of balancing columns, the pressure must be the same at all points in the same horizontal level.
3. Relative density $= \dfrac{\text{mass of a substance}}{\text{mass of an equal volume of water}}$
4. Boyle's law states that temperature remaining constant, the volume of a given mass of gas varies inversely as its pressure, $V \propto 1/P$
   or $PV = \text{constant}$.
5. Manometers are used for measuring pressure.
6. Pascal's law states that an increase in pressure applied at any point within a liquid at rest is transmitted equally in all directions to every other point in the liquid.
7. Archimedes' principle states that when a body is wholly or partially immersed in a liquid, it appears to lose some weight, which is equal to the weight of liquid displaced by it.

REVISION

I. Choose the correct answer:

1. Pressure at the midpoint of the liquid in a vessel
   a. is less than that at the surface. b. is greater than that at the bottom. c. is half that at the bottom.
2. Two solids of equal volume but different weights are submerged in water
   a. the loss of weight for both will be the same. b. the heavier object will lose more weight. c. they will have the same weight in water. d. they will displace different weights of water.
3. The apparent loss of weight of a body totally immersed in a liquid depends on
   a. the density of the body. b. the volume of the body. c. the weight of the body. d. the depth of which it is immeresed.
4. If the pressure of a given quantity of gas is tripled, and the temperature kept constant, the density
   a. is not changed. b. is tripled. c. is one third the initial pressure.
5. In an U-tube experiment, h_1 = height of liquid and h_2 = weight of water column, the relative density of the liquid is given by
   a. h_1/h_2. b. h_2/h_1. c. $h_2 - h_1$.
6. A falling barometer reading usually indicates
   a. a continuance of good weather. b. rise in temperature. c. change to better weather.
   d. approaching rain or storm.

7. The hydraulic jack is based on

a. Pascals' law. b. Boyle's law. c. Archimedes' principle. d. Principle of balancing columns.

II. Fill in the blanks:

1. Pressure is defined as the ________ per unit area.
2. The unit of pressure is ________ .
3. The pressure at a depth h in a liquid of density d is ________ .
4. The relative density of a substance is the ratio of the ________ to the ________ .
5. The U-tube method of determining relative density is based on the principle that ________ at points in the same horizontal line is equal.
6. The volume of a given mass of gas varies ________ with its pressure, the temperature being constant.
7. Manometers are used to measure ________ .
8. If the pressure to be measured is only slightly different from the atmosphere then the liquid in the manometer is ________ .
9. Closed tube manometers are used to measure pressures much ________ than atmospheric pressure.
10. The expression for relative density determined by U-tube and Hare's apparatus is

$$\frac{\text{height of the } \underline{\hspace{2cm}} \text{ column.}}{\text{height of the } \underline{\hspace{2cm}} \text{ column.}}$$

III. State whether true of false.

1. Pressure at a point inside a given liquid depends only on the depth of the point below the surface.
2. The U-tube cannot be used to determine the relative density of a liquid which is miscible in water.
3. The Boyle's law apparatus is used to measure high pressures.
4. If water and kerosene are poured into the two limbs of a U-tube respectively, water stands at a greater height than kerosene in the tube.
5. The loss of weight of a cork if fully immersed in water is greater than its weight in air.
6. The hydraulic brake is based on Pascals' law.
7. Bramah's press is based on the principle of balancing columns.
8. It is more difficult to lift a stone under water than on land.
9. The Bramah press is used for printing books.
10. Atmospheric pressure increases as height increases.

IV. Answer the following questions:

1. Define pressure. Calculate the pressure at a point within a liquid at rest.
2. What is the difference between density and relative density?
3. How will you use the U-tube to determine the relative density of a. A liquid which is immiscible

in water. b. A liquid which is miscible in water.

4. Describe the Hare's apparatus method for determining the relative density of a liquid.
5. How will you determine the relative density of a solid heavier than water using Archimedes' principle?
6. How will you determine the relative density of cork using Archimedes' principle?
7. How will you determine the relative density of a liquid by Archimedes' principle?
8. State and explain Boyle's law.
9. Describe the Boyle's law apparatus and show how it may be used to verify Boyle's law.
10. How will you measure pressure using the
    a. Open-tube manometer. b. Closed-tube manometer.
    Indicate the range of pressure each is suitable for.
11. The area of the smaller piston of a hydraulic press is 1 sq. m. and that of the larger piston is 5 sq.m. How much weight can be raised on the larger piston by a force of 100 kg on the smaller piston?
12. Draw a neat diagram of Fortin's barometer and label its parts.
13. What steps would you follow to read the atmospheric pressure from Fortin's barometer?

V. Problems:

1. A 5 cm cube of iron weighing 925 gm is submerged in water. It displaces ________ cc of water. This volume of water weighs ________ gm. The piece of iron will weigh ________ gm less in ________ than in air. The weight of the cube in water is ________.
2. Calculate the force of buoyancy on a stone of volume 1.5 cu.m, immersed in sea water of density 1030 kg/m^3. (Ans: 151141 N = 15.141 kN)
3. A body weighs 50 gm in air and 40 gm in water. Find its density. (Ans. 5 gm/cc.)
4. A body *A* weighs 7.55 gms in air, 5.15 gms in water and 6.35 gms in another liquid *B*. Calculate the relative density of *A* and *B*. (Ans. 3.15, .5)
5. Mercury of density 13.6 gm/cc and a liquid are placed in the limbs of a U-tube and the surface of mercury and the liquid are 3 cm and 28 cms respectively from their common surface. Find the density of the liquid. (Ans. 1.46 gm/cc.)
6. A piece of iron has a mass of 890 gm and volume of 100 cc. When this is immersed in water calculate
    a. the buoyant force of water on it. b. the weight of iron in water.
    (Ans. .98 N, .79 kg.)

4. Heat

Temperature and its measurement - thermometric scales - thermometers- mercury, alcohol, clinical and max/min -thermal expansion of solids , liquids and gases - heat energy and gas laws - heat transfer - conduction, convection and radiation.

4.1. Temperature and its measurement

Temperature and heat: Temperature is a measure of the 'hotness' or 'coldness' of a body. Temperature tells us how hot or cold a substance is and it is a condition of a body which determines the direction of flow of heat. This condition can be altered by adding or taking away heat from the body. Knowing the temperature does not tell us how much heat there is in a body. Heat is a form of energy which can be present in small or large quantities. Thus, the amount of heat in boiling water depends upon the quantity of water concerned. Two kilograms of boiling water contains twice as much heat as one kilogram of boiling water although both quantities of water are at the same temperature.

If there is a difference of temperature between two bodies, heat will pass from the body which is at the higher temperature to the body at the lower temperature, until both bodies come to the same temperature.

MEASUREMENT OF TEMPERATURE

Our sense of touch is quite reliable for comparing temperatures, but sometimes it can also prove misleading. Put one hand in hot water and the other in cold water for a few moments. Now put both hands together in warm water. The hand which was in hot water will give you the impression that it is now in cold water, while the hand which was in cold water will give you the impression that it is now in hot water. In this experiment, the 'hot' hand loses heat the moment it is placed in warm water and so feels cold. Besides being unreliable under certain conditions, our sense of touch does not help us to measure temperature or a change of temperature accurately.

THERMOMETER

An instrument used for the measurement of temperature is called a thermometer. The thermometer widely used today is the mercury thermometer.

Mercury thermometer : It consists of a thick-walled, properly annealed glass tube of uniform bore, at one end of which is blown a thin walled bulb (Fig 4.1). The bulb is usually of cylindrical form. The other end of the tube is sealed. The bulb and a portion of the stem are filled with

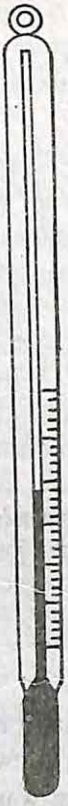


Fig. 4.1 A mercury thermometer

mercury. There is a graduated scale engraved on the stem. The scale is graduated by choosing two fixed temperatures as the lowest and highest marks on the scale. These are called the *fixed points* on the scale.

While measuring temperature, the freezing and boiling points of water under given conditions are taken as the standards of temperature. These two temperatures are always the same and can be easily found.

Determination of lower fixed point: In order to determine the *lower fixed point*, i.e., the freezing point of water, the unmarked thermometer is put into a funnel containing pure melting ice, so that the bulb and lower part of the stem are completely buried in the pieces of crushed ice (Fig.4.2). Below the funnel, a vessel may be placed to collect the water that drips from the melting ice. After several minutes, you will observe that the mercury stands at a constant level. A fine mark is made on the stem at this position. This is called the *lower fixed point* or *ice-point*.

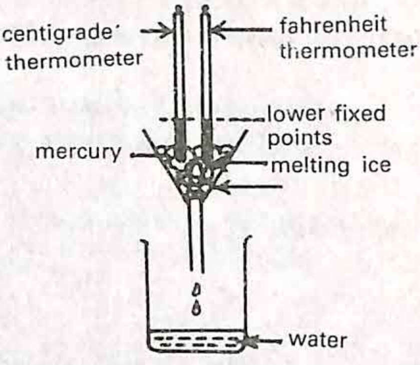


Fig. 4.2 Lower fixed point

Determination of upper fixed point: To determine the *upper fixed point*, a double walled copper vessel called a *hypsometer* is used (Fig. 4.3). This is fitted with a manometer at one side and an outlet for steam on the other side. Water

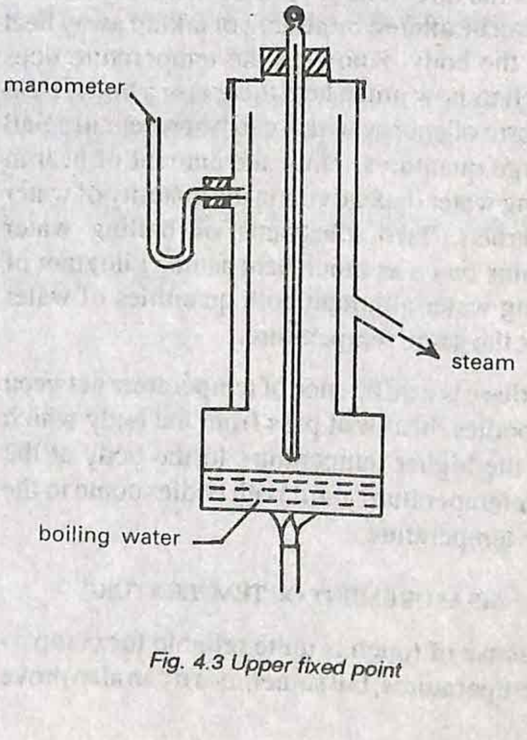


Fig. 4.3 Upper fixed point

is boiled in the lower part of the hypsometer and the thermometer is fixed so that it is not touching the water. This is done so that the bulb and mercury get the true temperature of steam. The thermometer is fixed so that the mercury thread is visible just above the top of the cork. The water is kept boiling till the thread of mercury remains stationary for some time. A fine mark is made on the stem in level with the mercury. This is called the *steam point* or upper fixed point.

The double walls reduce loss of heat and so prevent steam from condensing on the thermometer. The manometer indicates whether the pressure inside the hypsometer is the same as the atmospheric pressure.

4.2 Thermometer scales

Having determined the two fixed points, a scale is put on the stem of the thermometer. This is done by dividing the space between the two fixed points into a number of units called degrees, written as °.

There are different ways of dividing the space between the two fixed points. In one kind of thermometer, the space is divided into 100 equal parts. Here, the freezing point is marked 0° and the boiling point is marked 100°. The thermometer with this simple arrangement is called the Centigrade thermometer (Fig.4.4a). Each division or unit is called a degree of Celsius. This thermometer is the one generally used for all scientific purposes.

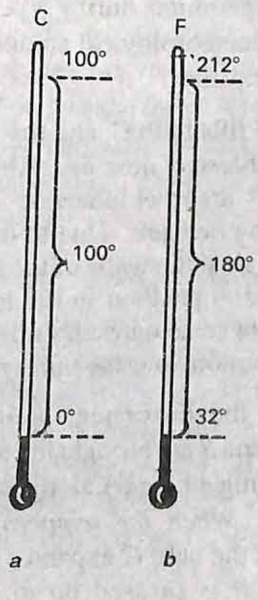


Fig. 4.4

Another kind of thermometer has the freezing point marked 32° and the boiling point marked 212° (Fig.4.4). The space between the two fixed points is divided into 180 divisions. A thermometer marked in this way is called the Fahrenheit thermometer. Each division or unit is called a degree of Fahrenheit.

From the figure it can be seen that the same range has been divided into 100 equal divisions in the Centigrade scale and 180 equal divisions in the Fahrenheit scale. So 1 degree Celsius is 1/100 of the range, i.e., 1 div and C degrees Celsius is C/100 divisions, of the range. If F is the same temperature on the Fahrenheit scale, it corresponds to F – 32 divisions from the ice-point which is F – 32/180 of the range.

Since the range is the same in both cases

$$\frac{C}{100} = \frac{F-32}{180}$$

$$\text{or} \quad C = \frac{100}{180}[F-32]$$

$$C = \frac{5}{9}[F-32] \text{ .... (i)}$$

$$\text{or} \quad F-32 = \frac{9C}{5}$$

$$\text{or} \quad F = \frac{9C}{5} + 32 \text{ ....(ii)}$$

So if we want to convert degrees Centigrade into Fahrenheit, we use (ii), and (i) to convert Fahrenheit to Centigrade.

Activity 1 : *Work out the problems given below and check your working with the solutions given.*

1. A Centigrade thermometer reads 50° C. Calculate its value in Fahrenheit from (ii).

$$F = \frac{9}{5} \quad C + 32$$

$$= \frac{9}{5} \times 50 + 32$$

$$= 90 + 32$$

$$F = 122^\circ F$$

2. The minimum temperature on a winter day in Ooty is 30°F. Find out what a Centigrade thermometer would read.

$$F = 30, \quad C = ?$$

From (i)

$$C = \frac{5}{9} \times (F - 32)$$

$$= \frac{5}{9} \times (30 - 32)$$

$$= \frac{5}{9} \times -2$$

$$= \frac{-10}{9}$$

$$= -1.11^\circ C$$

4.3 Thermometers

The mercury thermometer has already been described in section 4.1.

ALCOHOL THERMOMETERS

Mercury freezes at $-39^\circ C$ and so it is not used to measure temperature below $-30^\circ C$. For measuring lower temperature, alcohol may be used as a thermometric liquid. Alcohol freezes at $-115^\circ C$ and boils at 78°c. If we compare alcohol with mercury as a thermometric liquid we find that

(i) Alcohol has a narrower range of use, but the range extends much more than mercury on the low temperature side.

(ii) It expands much more than mercury for the same rise in temperature. The divisions on the alcohol thermometer are therefore larger. The expansion of alcohol is not as uniform as mercury, hence its divisions do not represent equal intervals of temperature.

(iii) It takes about the same amount of heat from a body as mercury does for the same volume.

As alcohol is transparent, it is coloured blue or red when used in the thermometer.

SIX'S MAXIMUM AND MINIMUM THERMOMETER

It is a form of the Fahrenheit alcohol thermometer (Fig. 4.5) which records both the highest and lowest temperatures during a period of time. It is used in meteorological stations and for agricultural purposes.

Alcohol fills bulb *C* and the tube down to *P*. *PMQ* is a thread of mercury. Above the mercury at *P* and *Q* are steel indicators *A* and *B*, with a small spring on each. Due to the springs being pressed against the walls of the tube, the indices can be in any position in the tube. There is a temperature scale on each limb; one graduated from the bottom and the other from the top.

Before the instrument is set to work, the indices *A* and *B* are brought in contact with *Q* and *P* by moving a magnet along the outer walls of the tube. *When the temperature rises*, the alcohol in the bulb *C* expands and the mercury meniscus *P* is pressed down. The thread of mercury moves up in the right limb of the U-

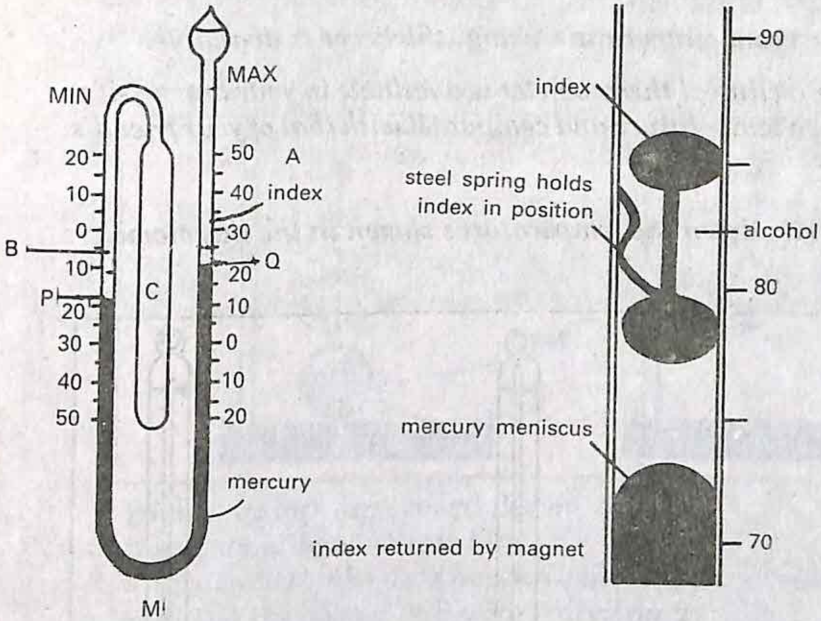


Fig. 4.5 Six's maximum and minimum thermometer

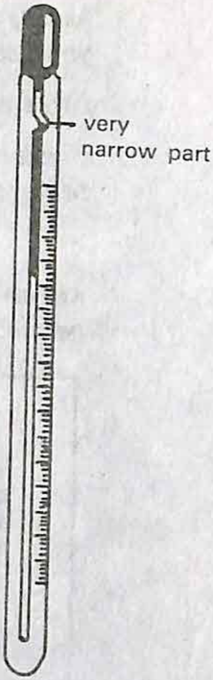


Fig. 4.6 The clinical thermometer

tube. Thus the mercury meniscus *Q* pushes the index *A* till there is no rise in temperature. The end of the indicator *A* which is nearer the mercury shows the maximum temperature. *When the temperature falls,* the alcohol in *C* contracts and the thread of mercury rises in the left limb. The meniscus *P* pushes the index *B* up. The end of indicator *B* which is nearer the mercury shows the minimum temperature. The indicators are re-set by using a magnet.

THE CLINICAL THERMOMETER

The thermometer with which we are all familiar is the one used by the doctor to read temperature. It is called the clinical thermometer (Fig. 4.6). Since the doctor only requires it for checking the temperature of the human body, the scale is graduated between 95°F and 110°F, which is as cold or hot as a human being can be. Each degree is divided into five equal parts because even small variations in the temperature of a patient are of great importance. The bulb of the thermometer is small, so that it may quickly reach the temperature of the patient's body. The bore of the thermometer is exceptionally fine and has a kink in it. When the mercury is heated, the great force of its expansion pushes it past the kink. As the thermometer is removed from the heat of the patient's body and comes in contact with the cooler air, the mercury contracts. The portion of the mercury below the kink retreats into the bulb whilst the portion of the mercury above the kink stays where it is, as it cannot squeeze its way back through the kink. The thermometer may now be kept until the arrival of the doctor. Once the reading has been taken, the thermometer is re-set by bringing the mercury in the bore back to the bulb with a jerk.

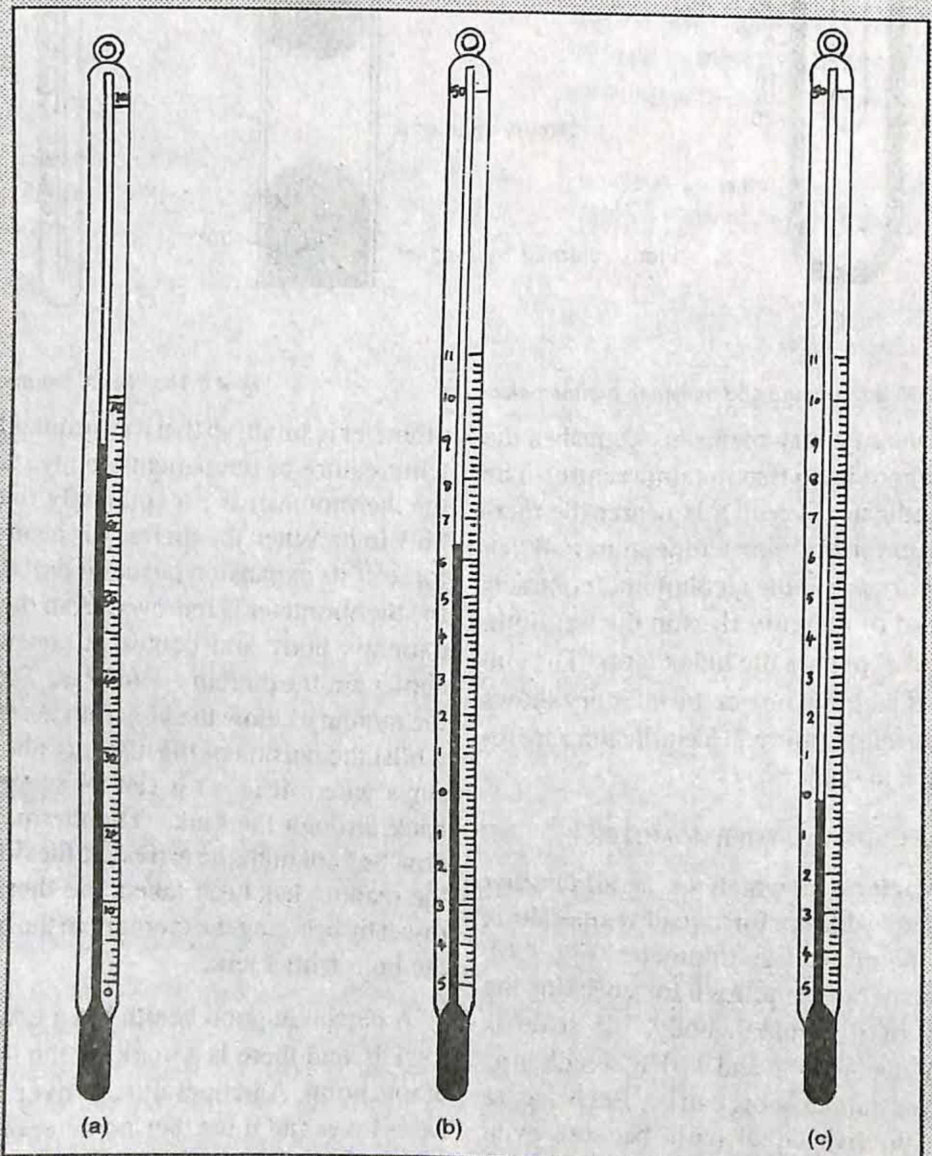
A person in good health has a temperature of 98.4°F and there is a mark on the thermometer at this point. A temperature of over 100°F indicates fever and if the thermometer registers over 105°F, it means that the patient is dangerously ill.

Activity 2: *Find out which of the above thermometers are available in your school and identify them.*

Find out the room temperature using whichever is available.

See whether a clinical thermometer is available in your home —if so take your own temperature and compare it with that of your friend's.

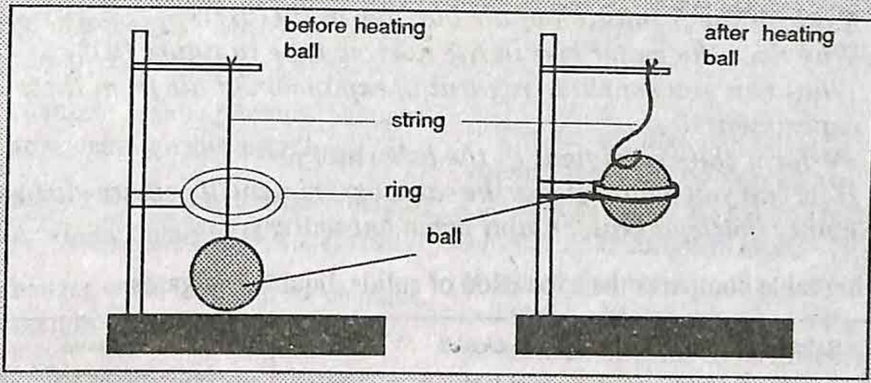
Activity 3: *Write down the temperatures shown in the thermometers below:*



(a) (b) (c)

4.4 Thermal expansion of solids, liquids and gases

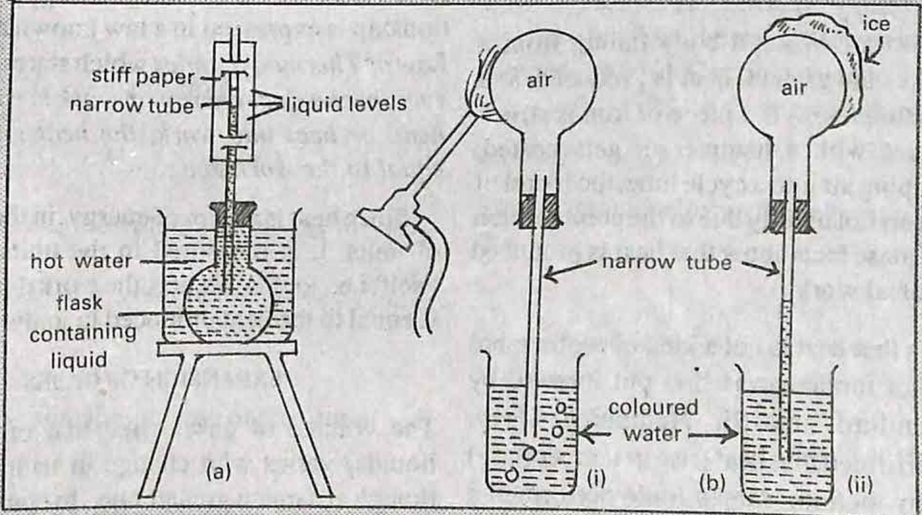
Activity 4: *The following diagram shows Gravesand's ball and ring experiment. Look at the diagram carefully and answer the questions below.*



1. *What does this experiment demonstrate?*
2. *How does it demonstrate this?*
3. *What do you think might happen if the ring were heated separately and then the heated ball were placed on it?*
4. *What would be the effect if the ring were chilled in a freezer and you tried to pass the ball through it?*

Do the above experiment in the laboratory.

Activity 5: *Look at the diagrams (a) and (b) below and answer the questions.*



1. *What does the experiment in figure (a) demonstrate?*
2. *What conditions do the liquid levels A, S and T correspond to?*

3. *What can you deduce from these liquid levels?*
4. *Describe the experiment in your own words.*
5. *Observe the experiment in the laboratory.*

1. *What does the experiment shown in figure (b) demonstrate?*
2. *Explain the formation of air bubbles in fig (b) (i).*
3. *Why does the water rise in the narrow tube in figure (ii)?*
4. *What can you conclude regarding expansion of air from these experiments?*
5. *Perform the experiment in the laboratory.*
6. *How can you demonstrate the same experiment if you are given an empty bottle, a balloon and some hot water?*

The following table compares the expansion of solids, liquids and gases:

S.N.	*Solids*	*Liquids*	*Gases*
1	Expansion is small.	Expansion is more than in solids.	Expansion is much greater than in liquids.
2	Does not need a container.	Expansion of container should be taken into account.	Expansion of container is negligible.
3	Not affected by pressure.	Not affected by pressure.	Is affected by pressure.
4	Expansion is different for different solids.	Expansion is different for different liquids.	If pressure is constant, the expansion is the *same* for all gases.

4.5 Heat energy and gas laws

Heat and work : When a body falling from a height strikes the ground, heat is produced, and its temperature rises. If a piece of iron is struck several times with a hammer, it gets heated. While pumping air into a cycle tube, the barrel of the pump gets hot mainly due to the compression of air. All these facts show that heat is produced by mechanical work.

The idea that heat is not a kind of motion, but is a result of motion, was first put forward by Count Rumford and Sir Humphrey Davy. Rumford affirmed that heat (rise in temperature) is caused by motion. James Joule performed a number of experiments on mechanical energy and heat, and not only showed that heat is a form of energy, but found the exact relationship between heat and mechanical energy. This relationship is expressed in a law known as the *First Law of Thermodynamics* which states that *whenever mechanical energy or work is converted to heat, or heat into work, the heat generated is equal to the work done.*

Since heat is a form of energy, in the SI system of units, it is measured in the units of energy itself, i.e., joules. Hence, the work done in joules is equal to the heat produced in joules or, $W = H$.

EXPANSION OF GASES

The volume of gases (like that of solids and liquids) varies with change in temperature, although at a much greater rate. In considering the change in volumes of solids and liquids, the effect of pressure is not taken into account, since the effect of a change in pressure on volume is negligible. But in the case of gases, even a small change in pressure produces an appreciable change in volume, although the temperature is kept constant. Therefore, to state the condition of a gas, it is necessary to mention its volume V, pressure P and temperature T. Any change in one of these, affects the other two. Such changes are governed by the *Gas Laws* given below:

1. Volume changes when pressure changes, temperature remaining constant (*Boyle's law*).
2. Volume changes when temperature changes, pressure remaining constant (*Charles' law*).
3. Pressure changes when temperature changes, volume remaining constant (*Pressure law*).

Boyle's law: This states that *the volume of a fixed mass of gas is inversely proportional to its pressure, temperature remaining constant.*

Charles' law: It states that *pressure remaining constant, the volume of a given mass of gas increases by* $\frac{1}{273}$ *of its volume at 0°C, for each degree Kelvin rise in temperature.*

Let V_0 represent the volume of a given mass of gas at 0°C. Then, from the law we have

$$\text{Volume at } 1^\circ\text{C} = V_0 + \frac{V_0}{273} \times 1$$

$$\text{Volume at } 2^\circ\text{C} = V_0 + \frac{V_0}{273} \times 2$$

$$\text{Volume at } 3^\circ\text{C} = V_0 + \frac{V_0}{273} \times 3$$

(i.e., for 1° rise, the volume increases by $\frac{V_0}{273}$

∴ for 2° rise, the volume increases by $\frac{V_0}{273}$

and so on.)

If V represents the volume at t°C, then,

$$V = V_0 + \frac{V_0}{273} \times t = V_0 \left(1 + \frac{t}{273}\right)$$

This is the mathematical statement of Charles' law. An interesting result arises when the temperature decreases to –273°C. For, substituting $t = -273$°C in the above, we have

$$V = V_0 \left(1 - \frac{273}{273}\right)$$

or $V = 0$

This means that, theoretically, at –273°C the volume of the gas becomes zero. In practice, of course, a gas becomes a liquid much before such a low temperature is reached. This temperature at which the volume of a gas becomes zero is called the *absolute zero,* and the scale of temperature having this as its lowest temperature is called the *absolute scale* of temperature. Since this scale of temperature is almost the same as another scale of temperature proposed by Lord Kelvin, temperatures on the absolute scale are expressed in terms of *Kelvin degrees* and is usually termed as *Kelvin,* omitting the word *degrees.* Thus, 5 Kelvin degrees is written as 5 Kelvin or 5K. In this scale of temperature, each Kelvin corresponds to each degree celsius, the only difference being that in the celsius scale, the 0°C corresponds to the ice-point, whereas in the absolute scale, the zero corresponds to a temperature of 273°C below the ice-point. Hence, a temperature of t°C corresponds to

$$T = (273 + t) \text{ degrees absolute}$$

or $T = (273 + t)$ K

The diagram below will help you understand this.

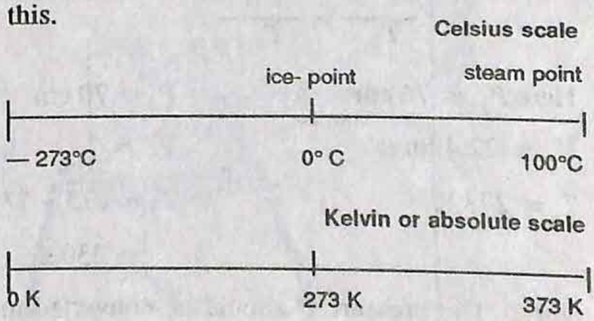


Fig. 4.7 Celsius and Kelvin scales

You will notice that both the scales shown here contain 373 degrees. Thus, though the temperatures on both the scales are different, the value of one degree in each is the same.

or, 1 degree C = 1 degree K.

Another statement of Charles' law is, *pressure remaining constant, the volume of a given mass of gas varies directly with its absolute temperature.*

or $V \propto T$

or $\frac{V}{T}$ = constant, *if P is constant.*

Pressure law: The two statements of pressure law are

a. *Volume remaining constant, the pressure of a given mass of gas increases by $\frac{1}{273}$ of its pressure at 0°C per Kelvin rise in temperature.*

b. *Volume remaining constant, the pressure of a given mass of gas varies directly as its absolute temperature.*

or $P \propto T$

or $\frac{P}{T}$ = constant

Therefore, from the three Gas Laws we have,

PV = constant (Boyle's law) (T constant)

$\frac{V}{T}$ = constant (Charles' law) (P constant)

$\frac{P}{T}$ = constant (Pressure law) (V constant)

These three can be combined into one statement.

$\frac{PV}{T}$ = constant

and is sometimes written as

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

where, P_1 and V_1 represent the pressure and volume of a gas at a temperature T_1 and P_2 and V_2 represent the pressure and volume of the same gas at a temperature T_2.

Activity 6: ***Work out the following problems and check your working with the solutions.***

Example 1

A certain mass of gas occupies a volume of 22.4 litres at 0°C and 76 cm pressure. What is its volume at 57°C and 70 cm pressure?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Here P_1 = 76 cm $\qquad P_2$ = 70 cm

V_1 = 22.4 litres $\qquad V_2$ = ?

T_1 = 273 K $\qquad T_2$ = 273 + 57

= 330 K

Note: The pressure P should be converted to pascals, but since the conversion factor on both sides of the equation cancels out, in all problems involving $\frac{PV}{T}$ = constant, the pressure may be written in cm of mercury.

$$\frac{76 \times 22.4}{273} = \frac{70 \times V_2}{330}$$

$$V_2 = \frac{330 \times 76 \times 22.4}{273 \times 70}$$

$$= \frac{2675}{91}$$

$$= 29.4 \text{ litres.}$$

Example 2

The volume of a given mass of gas under constant pressure is 10 litres at 27°C. Find the volume of the same mass of gas at 0°C.

Under constant pressure

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$V_1 = 10$ litres $\qquad V_2 = ?$

$T_1 = 273 + 27 = 300$ K $\qquad T_2 = 273$ K

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{10}{300} = \frac{V_2}{273}$$

$$V_2 = \frac{10 \times 273}{300}$$

$$= 9.1 \text{ litres.}$$

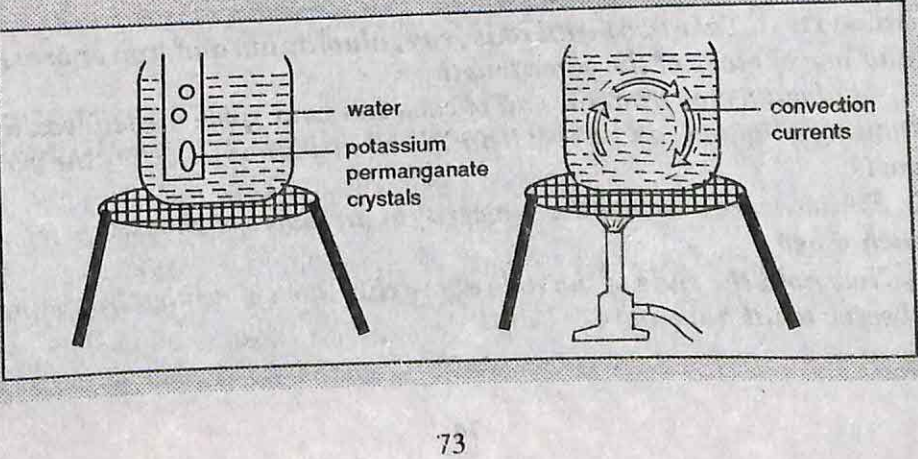
4.6 Heat transfer

You have already learnt about heat transfer in class 7. The three modes of heat transfer are

1. *Convection* : The process by which heat is transmitted in liquids and gases from place to place by the movement of particles is called convection.
2. *Conduction* : When heat is transmitted along a body from particle to particle, without the movement of the particles from their positions, the process is called conduction.
3. *Radiation* : When heat is transferred from one place to another, without the presence of any intervening medium, the process is known as radiation.

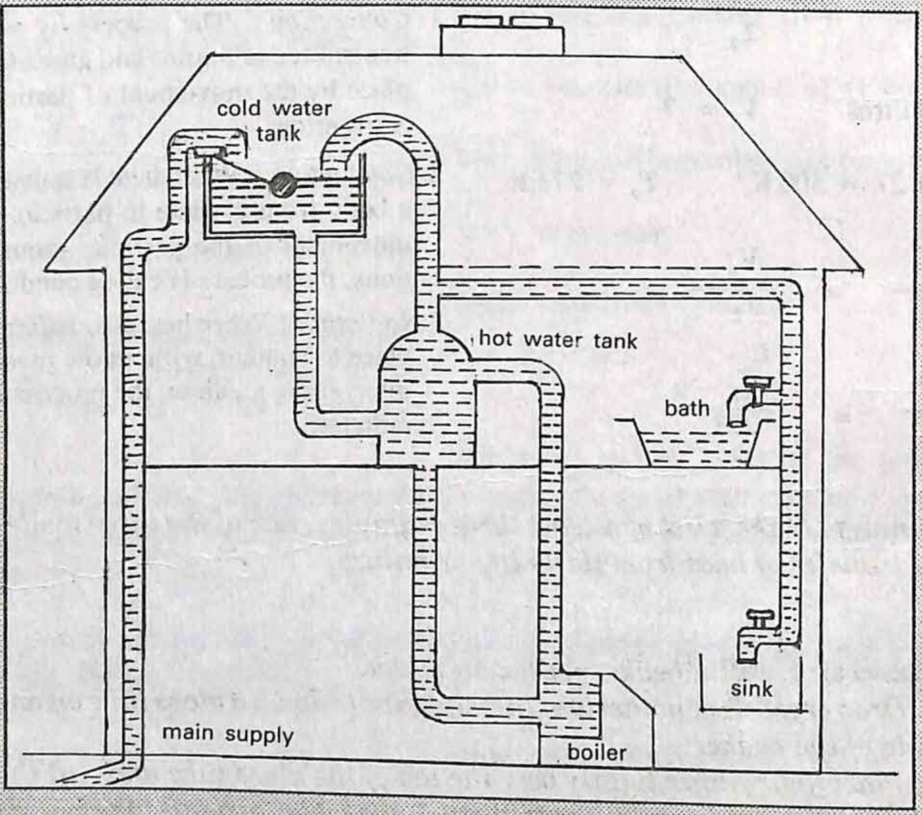
Activity 7: *Make a list of atleast three examples each of the three modes of transfer of heat from daily life or nature.*

Activity 8: *1. Fill a beaker with cold water.*
2. Drop crystals of potassium permanganate down a glass tube on one side of the beaker.
3. Place your finger tightly over the top of the glass tube and lift the tube slowly taking care not to disturb the water around the crystals at the bottom.
4. Now heat the beaker gently. What happens? Why?



Activity 9: *Convection currents take place in air. Explain why ventilators (small windows at the top of the room) are provided in rooms ,on the basis of the above statement.*

Activity 10: *The diagram below shows a household hot water system. Label the pipes carrying hot water and cold water and show by arrows the direction of flow of the water in the pipes.*



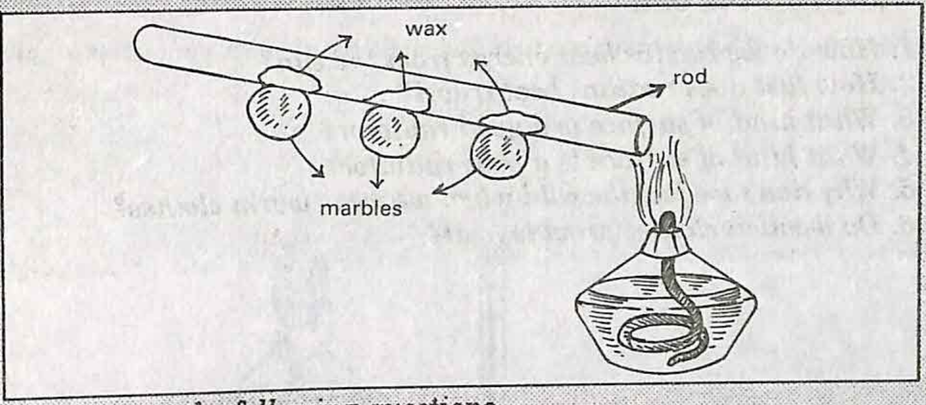
Explain how hot water flows through to the bathroom and sink.

Activity 11: *1. Take two metal rods , say , aluminium and iron or brass, and one of glass of the same length.*

2. At about 5 cms from the end of each rod pour some melted wax by holding a lighted candle over it and fix a marble on to it before the wax cools.

3. Fix two more marbles the same way at distances of about 3 cm from each other.

4. Now hold the ends of the rods above the flame of a spirit lamp and observe what happens ?



Now answer the following questions.

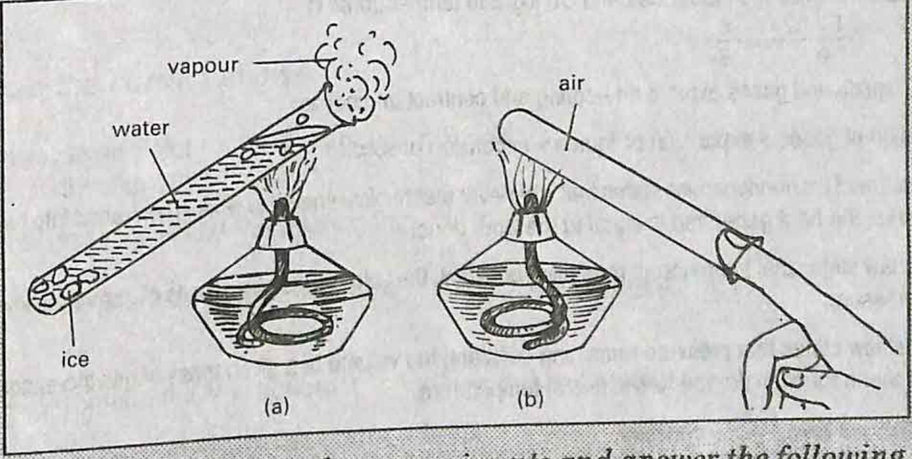
(i) Of the three marbles fixed to any rod, which falls off first ? Why?

(ii) Of the three rods, from which rod does the marble fall off first? Why?

(iii) Which of the three rods is the best conductor of heat ? Which is the worst ?

(iv) What are bad conductors of heat called ?

(v) Are the metals equally good conductors ?



Activity 12: *Perform the above experiments and answer the following :*

1. *What does fig. (a) demonstrate ?*
2. *Does the ice melt ? Why?*
3. *What do we conclude from this experiment?*
4. *What does fig. (b) demonstrate ?*
5. *Does the heat reach the finger ? Why?*
6. *What does this experiment demonstrate ?*

Activity 13: ***Find out:***

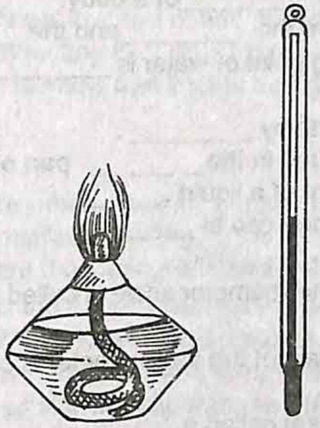
1. How do we receive heat energy from the sun?
2. How fast does radiant heat travel?
3. What kind of surface is a good radiator?
4. What kind of surface is a poor radiator?
5. Why don't we feel the cold when we wear warm clothes?
6. Do woollen clothes provide heat?

Basic concepts

1. In a Centigrade or Celsius thermometer, the range between the ice-point and steam point is divided into 100 divisions.
2. In a Fahrenheit thermometer, the range between ice-point (32°F) and steam point (212°F) is divided into 180 equal divisions.
3. The relation connecting Fahrenheit and Centigrade temperatures is
   $$\frac{F-32}{9}=\frac{C}{5}$$
4. Solids, liquids and gases expand on heating and contract on cooling.
5. Expansion of gases > expansion of liquids > expansion of solids.
6. The first law of thermodynamics states that whenever mechanical energy or work is converted into heat and vice versa, the heat generated is equal to the work done.
7. Boyle's law states that temperature remaining constant, the volume of a given mass of gas varies inversely as its pressure.
8. Charles' law states that pressure remaining constant, the volume of a given mass of gas increases by $\frac{1}{273}$ of its volume for each degree Kelvin rise of temperature.
9. From the gas law, $\frac{PV}{T}$ = constant.
10. During convection, heat is transmitted in liquids and gases from place to place by the movement of particles.
11. During conduction heat is transmitted along a body from particle to particle without the movement of the particles from their positions.
12. During radiation, heat energy is transferred from place to place without the presence of any intervening medium.

Some investigatory projects/activities

I. Draw diagrams to show ways in which we use heat conductors and insulators in everyday life.



1. *In the above experiment, what can you expect?*
2. *How does the heat energy reach the thermometer?*
3. *Give reasons why we can say that the heat does not reach the thermometer by conduction or convection.*

REVISION TIME

I. Choose the correct answer:

1. The lower fixed point on the Fahrenheit scale is
   a. 0°. b. 32°. c. 180°. d. –32°.
2. Charles' law is given by the relationship
   a. $\frac{PV}{V}$ = constant when T is constant. b. $\frac{V}{P}$ = constant if V is constant.
   c. $\frac{P}{T}$ = constant if V is constant. d. $\frac{PV}{T}$ = constant.
3. At constant temperature, if the pressure of a gas is doubled, its volume
   a. is halved. b. is doubled. c. remains the same.
4. Absolute zero is the temperature at which
   a. a gas liquifies. b. ice melts. c. the volume of the gas becomes zero.
5. Radiation is the process in which heat energy is transferred
   a. without any medium. b. when the particles of medium move from place to place. c. when the particles do not move from their place.

II. Fill in the blanks:

1. Temperature is a measure of ________ or ________ of a body.
2. The two thermometer scales most used are the ________ and the ________
3. On a Centigrade thermometer, the freezing point of water is ________ degrees and the boiling point is ________ degrees.
4. Heat is transferred from the sun to the earth by ________ .
5. The hottest water in a hot water tank is found in the ________ part of the tank.
6. As the pressure increases, the boiling point of a liquid ________ .
7. The heat from the sun reaches us by the process of ________ .
8. A bad conductor of heat is called an ________ .
9. The maximum fixed temperatures on the thermometer scale is called the ________ ________ ________ .
10. The minimum fixed temperature on the scale of the thermometer is called the ________ ________ ________ .
11. The upper fixed point is found using a vessel called a ________ .
12. In studying the expansion of solids and liquids, the effect of ________ is not taken into account.
13. The theoretical temperature at which the volume of a gas becomes zero is called the ________ ________ .
14. A household hot water system is based on ________ of heat.
15. A glass greenhouse depends on ________ of heat.
16. Wood, cork, asbestos are good ________ of heat.

III. State whether true or false :

1. The Fahrenheit scale is from 0 to 212 degrees.
2. A clinical thermometer is usually graduated in the Centigrade scale.
3. The ice-point on the Centigrade scale is zero degrees.
4. The range of the alcohol thermometer is 0 - 100°C.
5. The melting point of ice is the absolute zero of temperature.
6. All metals expand by the same amount when heated through the same range of temperature.
7. All gases expand by the same amount when heated through the same range of temperature under the same conditions of pressure.
8. Heat energy is measured in joules.
9. Charles' law gives the relation between pressure and volume at constant temperature.
10. One degree on the Kelvin scale is equal to one degree on the Centigrade scale.

IV. Answer the following questions:

1. Distinguish between heat and temperature.
2. How is the lower fixed point marked on a thermometer?
3. How is the upper fixed point marked on a thermometer?
4. What are the two main thermometric scales used? Obtain a relation connecting a temperature on the Centigrade scale and Fahrenheit scale.
5. Why is mercury preferred as a thermometric substance?
6. Describe the clinical thermometer.
7. Describe experiments to demonstrate conduction, convection and radiation.

V. Answer the following in detail:

1. Describe the construction and working of Six's maximum and minimum thermometer.
2. State and explain Charles' law and define absolute zero.
3. Obtain the relation connecting P, V and T by combining the three gas laws.
4. Describe experiments to show that liquids and gases are poor conductors of heat.

VI. Problems:

1. Convert 20°C to a Fahrenheit reading. (Ans. 68°F)
2. Convert 14°F to a Centigrade reading. (Ans. –10°C)
3. At what temperature are the Centigrade and Fahrenheit readings the same? (Ans. –40°C)
4. At what temperature is the Fahrenheit reading double the Centigrade reading? (Ans. 320°F)
5. (i) Express 57°C, –23°C as Kelvin temperatures. (Ans. 330 K, 250 K)
   (ii) Convert 298 K, 273 K to centigrade temperatures. (Ans. 25, 0°C)
6. (i) Express 98°F, 0°F as Kelvin temperatures. (Ans. 309.7 K, 255.2 K)
   (ii) Convert 373°K, 0°K to Fahrenheit temperatures. (Ans. 212°F, –459.4°F)
7. A gas has a volume of 100 cm^3 at 27°C. What is its volume at 0°C, the pressure remaining constant? (Ans. 91 cm^3)
8. Find the temperature at which 95 cm^3 of gas measured at 12°C becomes 120 cm^3 at constant pressure. (Ans. 87°C)
9. A certain quantity of gas at 75 cm pressure and 27°C is heated to 99°C, the volume remaining constant. What is the new pressure? (Ans. 93 cm of Hg.)
10. To what temperature must a given mass of air at 20°C be heated, in order that its pressure may be doubled, the volume remaining constant? (Ans. 313°C)

5. Light – (I)

Reflection- plane mirror, spherical mirrors - mirror formula - refraction (glass slab, prism for deviation, and dispersion) - colours of spectrum - lenses (image formation, magnification and power)

5.1 Reflection

1. PLANE MIRROR

We have already learned that most objects are made visible when light falling on them is reflected back to our eyes. The rays of light that fall upon a body are called incident rays, while those that are sent back by the body are called reflected rays.

A mirror is a smooth, highly polished surface, designed to reflect a maximum amount of light. Mirrors usually consist of pieces of glass silvered on one surface. Some are flat and are called plane mirrors, while others may be curved mirrors. Any smooth polished metal or surface may serve as a mirror.

Experiments show that all cases of reflection are governed by two laws :

1. The incident ray, the normal and the reflected ray all lie in the same plane.

2. The angle of incidence is equal to the angle of reflection or

$$\angle i = \angle r$$

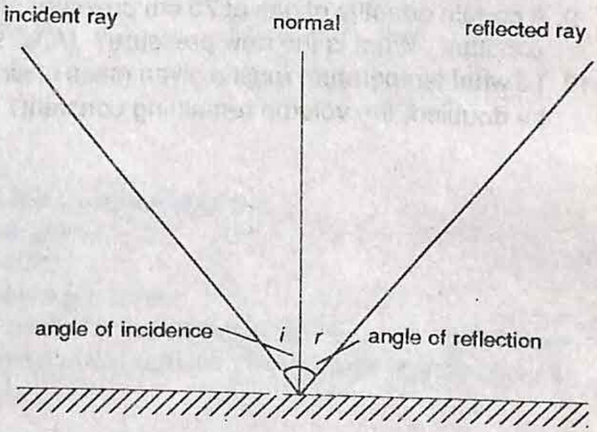


Fig. 5.1 Laws of reflection

IMAGE FORMED IN A PLANE MIRROR

Take a mirror and look into it. What do you see? First, of course, you see your face, and then you can see many of the objects in the room. At first it may seem to you that you are looking into a room exactly like yours. But, if you look carefully you will notice that the 'image room' is not quite the same. For one thing, you may notice that the clock in the 'image room' seems to move backwards and the numbers also are reversed sideways. A calendar on the wall in the 'image room' is also difficult to read. The second thing you will notice is that your face and other objects seem to be the same size in the 'image room'. Another thing about the image in the plane mirror is that when your face is far from the mirror the image also appears to be far. As you move closer to the mirror, your image also moves closer. In fact your image is as far behind the mirror as you are in front of it. Apart from all this, the images in a plane mirror are not really there. There is actually nothing behind the mirror. Such images are called *virtual images*.

From the above discussion we conclude:

1. The image formed by a plane mirror is as far behind the mirror as the object is in front of it.
2. The size of the image is the same as the size of the object.

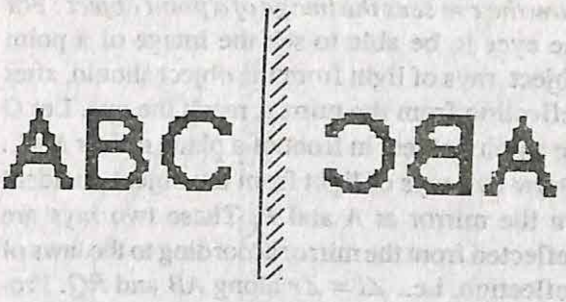


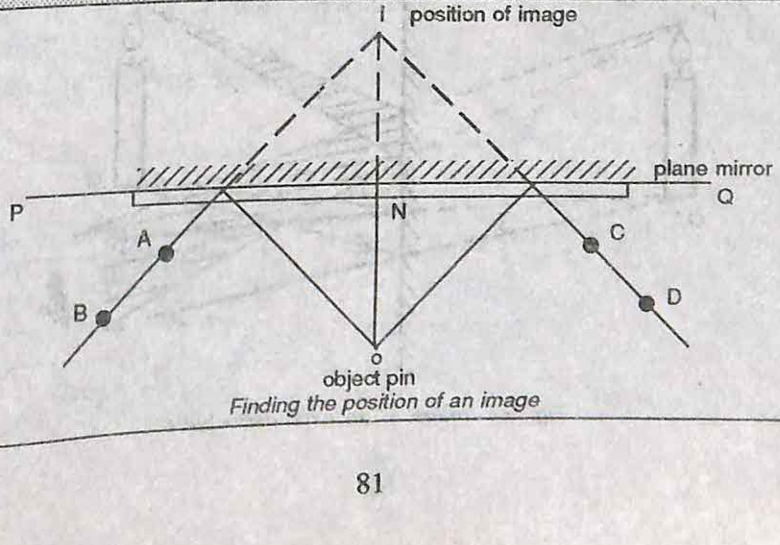
Fig. 5.2 Lateral inversion

3. The image is laterally inverted, i.e., inverted sideways (Fig. 5.2).
4. The image is virtual.

The first characteristic of the image in a plane mirror which is listed above can be demonstrated by the following experiment.

Activity 1: To show that the image is as far behind the mirror as the object is in front of it.

Place a plane mirror on a line PQ drawn on a paper. Stick an object pin O a few cm from the mirror. Place two pins so that they are in line with the image of O. Similarly, view the image along CD and place two pins at C and D so that they are in line with the image. Remove the mirror and join the points AB and produce it backwards. Join CD and produce it backwards too. Mark the point I of the intersection of lines AB and CD. Since the image lies along AB as well as along CD, its true position lies along the intersection I of AB and CD. Hence, I is the image of O. Join OI to meet the mirror at N. Measure ON and NI. It will be found that ON = NI.



Finding the position of an image

How the eye sees the image of a point object : For the eyes to be able to see the image of a point object, rays of light from the object should, after reflection from the mirror, reach the eye. Let O be a point object in front of a plane mirror MM_1. Draw two rays of light from the object, incident on the mirror at A and P. These two rays are reflected from the mirror according to the laws of reflection, i.e., $\angle i = \angle r$ along AB and PQ. Produce AB and PQ backwards to meet at I. For an eye placed between B and Q, the image is seen at I.

How the eye sees the image of an extended object: Every point on an extended object acts as a point source and forms the image of that point exactly as in the preceding section. For clarity, only two points situated at the extreme ends of the object have been chosen such as P and Q. The image of these points are formed at P^1 and Q^1. Thus P^1Q^1 is the image of PQ (Fig 5.4).

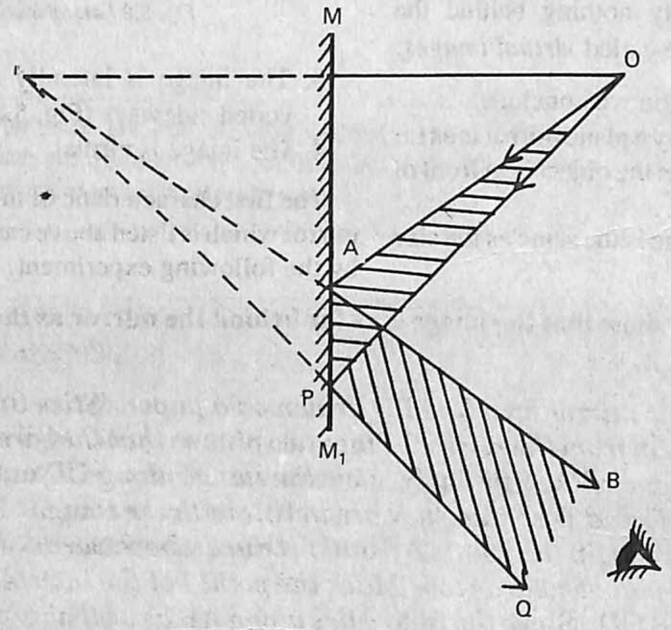


Fig. 5.3 Image of a point object

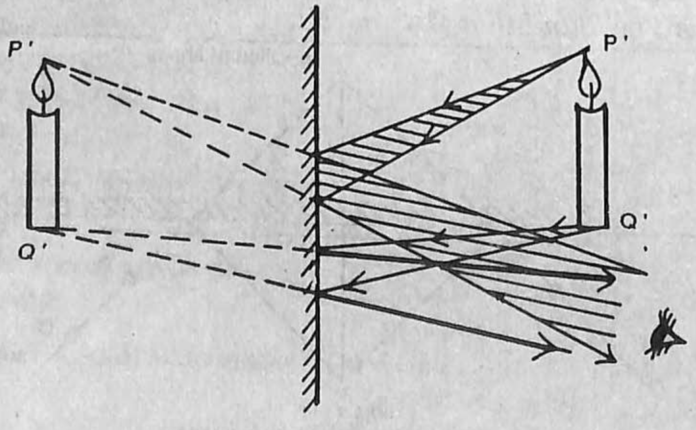
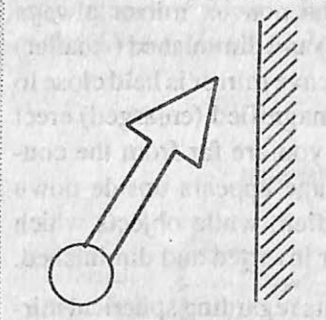
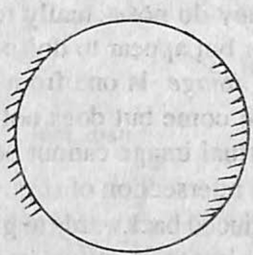


Fig. 5.4 Image of an extended object

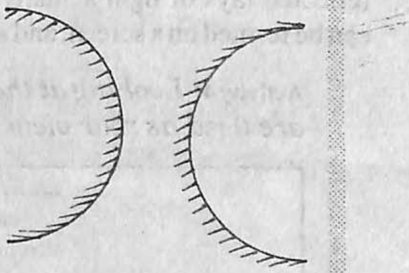
Activity 2: *Draw this diagram in your notebook and show the formation of the image. Mention how the characteristics of an image in a plane mirror are obtained in the diagram. The rays should be drawn using the laws of reflection.*



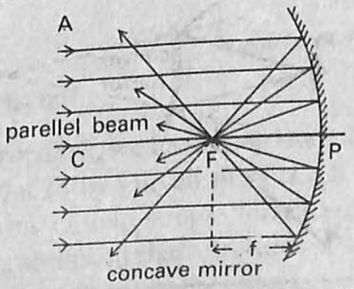
Activity 3: *Recall what you have learnt earlier and answer the questions given below.*

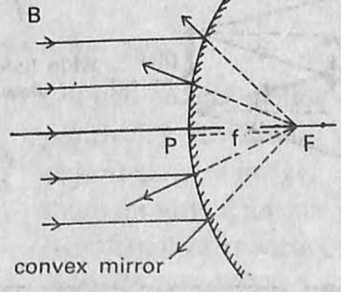


1. *Which of the two mirrors AB and CD is convex? Which is concave?*
2. *Mark the centre of curvature of the mirrors and define it.*
3. *Mark the radius of curvature of each mirror.*
4. *Which is the pole of each mirror?*
5. *Draw the principal axis and define it.*
6. *Looking at the diagram below define principal focus and focal length of a curved mirror. Indicate which points correspond to the principal focus and which distance to the focal length.*



Which of the foci is real? Which is virtual?
Which line is the principal axis?





Look into a convex and a concave mirror. The image seen in the convex mirror always appears upright (erect) and diminished (smaller) in size. When the concave mirror is held close to your face, you see a magnified (enlarged) erect image of yourself. If you are far from the concave mirror, your image appears upside down (inverted) and magnified, while objects which are still farther appear inverted and diminished.

The following points regarding spherical mirrors should be remembered:

1. Any line drawn from the mirror surface to the centre of curvature is a *normal* to the surface.
2. Rays are shown by dotted lines behind a mirror, they do not actually reach behind the mirror but appear to do so.
3. A *virtual image* is one from which light appears to come but does not actually do so. A virtual image cannot be formed by the direct intersection of rays. They have to be produced backwards to give the position of the image. A virtual image cnnot be formed on a screen, and is always upright and erect.
4. *A real image* is one through which the reflected rays of light actually pass. They can be formed on a screen, and are inverted.

Location of images in curved mirrors : The following properties of rays are made use of while locating images:

1. A ray parallel to the principal axis, after reflection, passes through the focus.
2. A ray through the focus is reflected parallel to the principal axis.
3. A ray through the centre of curvature is normal to the mirror, and so it is reflected back along its path.

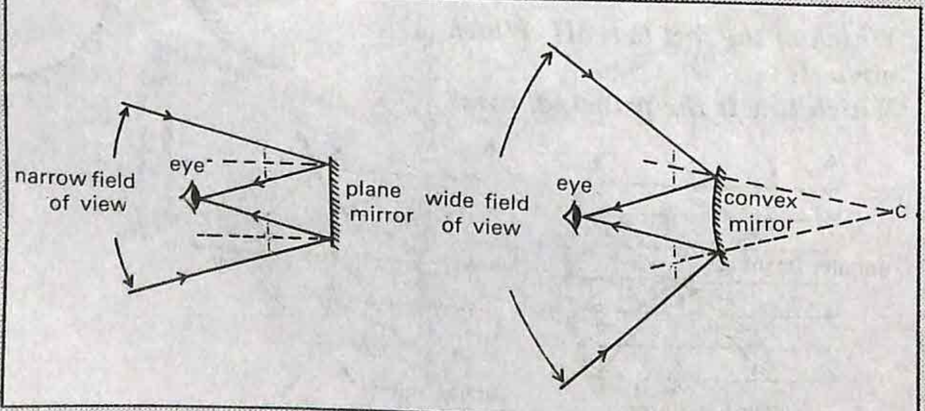
Usually, two of the above are sufficient to locate the position of the image. The laws of reflection of light hold good for curved mirrors also.

When rays of light come from a distant object, the light is taken as a parallel beam and the object is said to be at infinity (∝) .

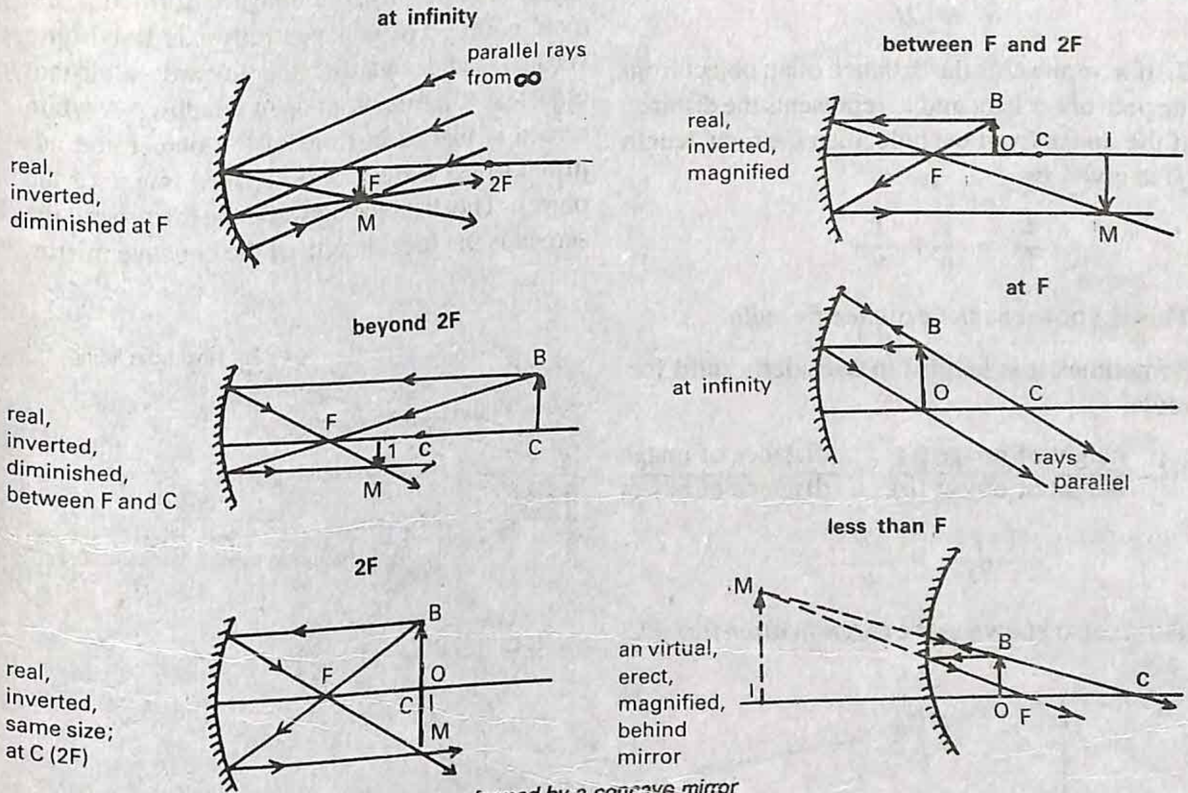
If you look into a concave mirror and bring a lighted candle close to it slowly, you will notice that the image gets larger as the candle approaches the mirror. You will also notice that when the candle is taken very close to the mirror, an erect, magnified image is formed.

On the other hand, if you repeat this procedure with a convex mirror, you will find the image is always erect and smaller than the size of the object.

Activity 4: *Looking at the diagram below , explain why convex mirrors are used as rear view mirrors in cars and buses.*



Activity 5: *Using at least two of the properties, of rays draw the following ray diagrams in your notebook. Draw them as large as possible.*



Images formed by a concave mirror

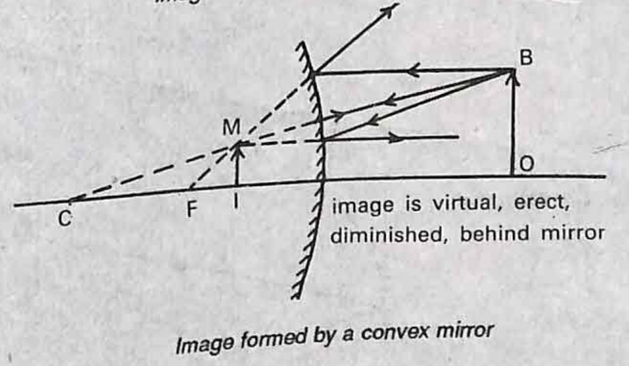


Image formed by a convex mirror

5.2 Mirror formulae

In the previous sections, we have been studying the images produced by curved mirrors. It is possible by means of two simple formulae to determine the location and characteristics of the image for various positions of the object.

In all our calculations we follow the '*real is positive*' convention. Values for distances of objects and real images are always *positive* and those for virtual images are *negative*. Also, the focal length of a concave mirror, which has a real focus is *positive* and the focal length of the convex mirror which has a virtual focus is *negative*.

I. The relation between the radius of curvature (r) and focal length (f) is

$$r = 2f$$

II. If u represents the distance of an object from the pole of a mirror and v represents the distance of the image from the pole, then the focal length (f) is given by

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

This is known as the *distance formula.*

Sometimes it is helpful to consider a third formula:

$$\text{III. } \frac{\text{height of image } (i)}{\text{height of object } (o)} = \frac{\text{distance of image}}{\text{distance of object}}$$

$$\frac{I}{O} = \frac{v}{u}$$

This is also known as the *magnification formula.*

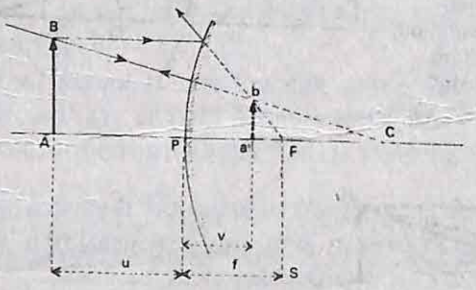


Fig. 5.5 (a) Magnification : Convex mirror

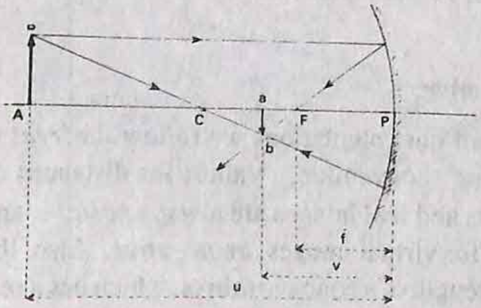


Fig. 5.5 (b) Magnification : Concave mirror

DETERMINATION OF THE FOCAL LENGTH OF A CONCAVE MIRROR

1. Distant object method (approximate method): This method is based on the fact that when the object is at infinity, the image is formed at the focal point. The concave mirror is fixed on a vertical stand and directed towards a distant object, say, a tree or an open window. A white screen is placed in front of the object and adjusted to get a clear, well-defined image of the object. The distance between the mirror and the screen is the focal length of the concave mirror.

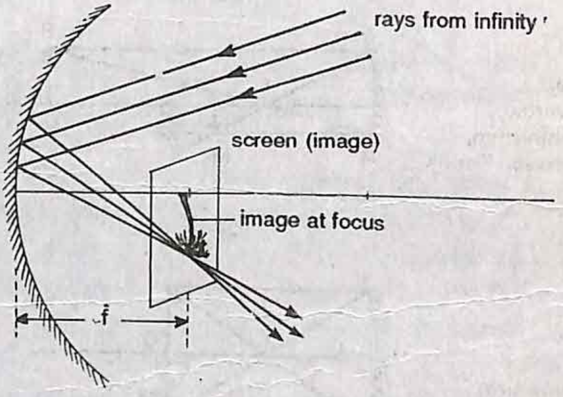


Fig. 5.6(a) Distant object method

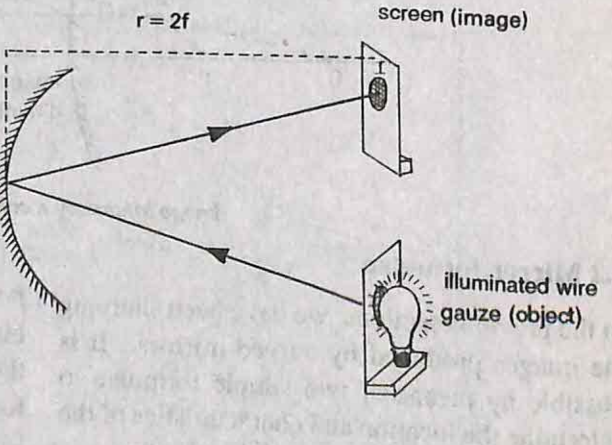


Fig 5.6(b) Normal reflection method

2. *Normal reflection method* : An illuminated wire gauze is used as the object. When the object is at the centre of curvature the image is also formed at the centre of curvature, so the screen is placed next to the object (Fig. 5.6 b). The distance between the object or image and the pole gives the radius of curvature r. Half this distance gives the focal length.

$$f = \frac{r}{2} \text{ metres}$$

3. *Object and image method (u-v method)* : An illuminated wire gauze, the concave mirror and screen are arranged as shown in Fig. 5.6.c Care is taken to see that the pole of the mirror is in the same line as the centre of the object. The object is placed at a distance greater then $2f$. The image will be formed between C and F and will be real and diminished. The screen is adjusted to get a clear, well-defined image of the object. The distances of the object (u) and screen (v) from the pole of the mirror are measured with a metre scale. The experiment is repeated for two other values of u greater than $2f$.

The object (illuminated wire gauze) is now placed between F and C and the position of the screen is adjusted beyond C to get a clear, well-defined image of the object. The image is real, inverted and magnified. The distances u and v are measured as before and the experiment repeated for two other values of u between F and C. Focal length f is calculated using the formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ or $f = \frac{uv}{u+v}$ in each case, and the mean value is found.

The readings are recorded as shown below:

Image	u m	v m	uv m^2	$u+v$ m	$f = \frac{uv}{u+v}$
diminished	2 3				
magnified	1 2 3				

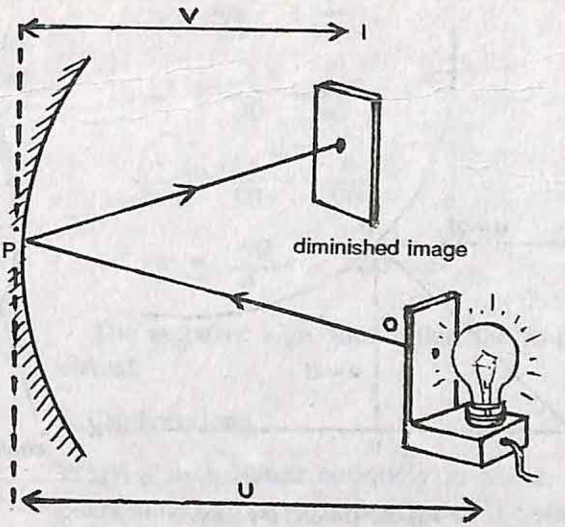


Fig. 5.6 c The U-V method : Object distance greater than 2f

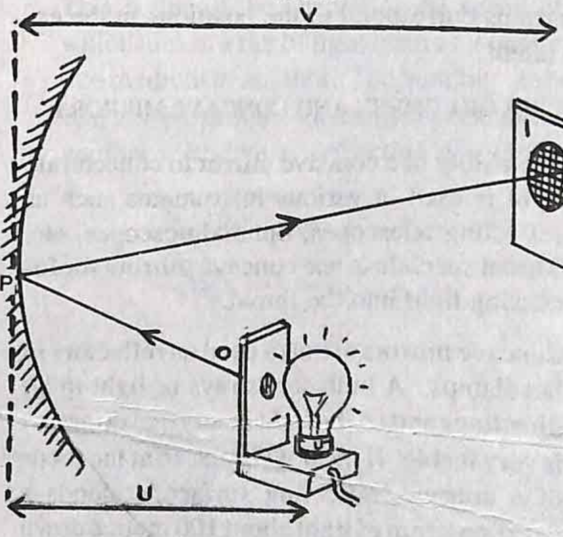


Fig. 5.6 (d) Object between f and c

With the readings, if a graph is plotted between u and v, a curve is obtained. A point P is chosen on the curve for which $u = v$. This is done by drawing the bisector of the right angle between the axes of X and Y. The point where this touches the curve is the point for which $u = v$. At this point $u = v = 2f$ because only at $2f$ is $u = v$.

Hence $f = \frac{u}{2} = \frac{v}{2}$

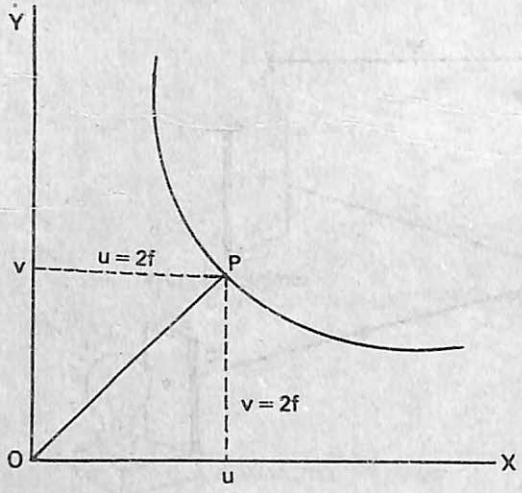


Fig. 5.7 Graph : u-v method

Compare the various positions of the object and image in the experiments with the ray diagrams on page 85. Which of the positions in the diagrams correspond to the positions in the experiment?

USES OF CONVEX AND CONCAVE MIRRORS

1. The ability of a concave mirror to concentrate light is used in various instruments such as reflecting telescopes, ophthalmoscopes, etc. Throat specialists use concave mirrors for focussing light into the throat.
2. Concave mirrors are also used as reflectors in headlamps. A bulb sends rays of light in all directions and so the light in any one direction is very feeble. If the bulb is placed at the focus of a concave reflecting surface, it sends a dazzling beam of light about 100 metres down the road (Fig. 5.8).

The figure gives an idea of how the headlights of a car work. Only a few rays of light have been shown.

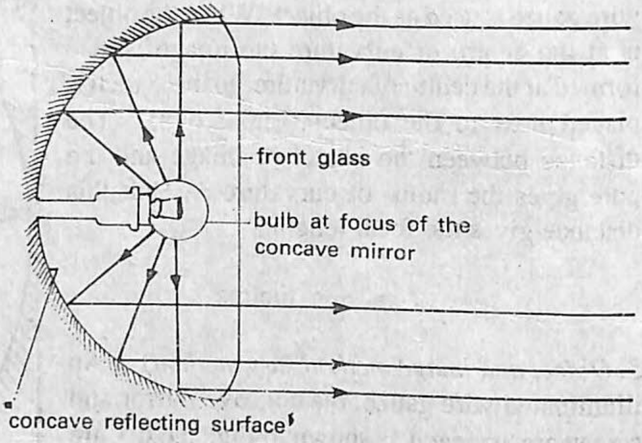

front glass
bulb at focus of the concave mirror
concave reflecting surface

Fig. 5.8 A headlamp

3. The searchlight works on the same principle as the headlamp. It is used in war for spotting aircraft, and in peacetime for guiding them. In the place of the small bulb, a powerful electric arc lamp is kept at the focus of the concave reflecting surface. An intense beam of light is sent out which can be directed toward a particular spot and can be viewed by airmen or even by ships at sea.
4. A shaving mirror is a concave mirror and it forms an erect, magnified and virtual image of an object placed between the focus and the pole. If a man brings his face close enough to a concave mirror, he sees a magnified virtual image of his face in the mirror.
5. Rear view mirrors in cars and buses are convex mirrors used to get a view of the traffic in the rear. All real objects in front of the mirror form erect, diminished and virtual images lying between the focus and the pole of the mirror. The driver can therefore get a view of everything behind him, by simply looking into this mirror.

Activity 6: *The following problems are worked out for you. Try to work them out yourself and then check with the solutions.*

Example 1

A concave mirror has a focal length of 30 cm. An object 5 cm high is placed at a distance of 50 cm from the mirror. Find the position and height of the image.

Here $f = 30$ cm $\quad O = 5$ cm

$u = 50$ cm $\quad I = ?$

$v = ?$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{30} = \frac{1}{50} + \frac{1}{v}$$

$$\text{or} \quad \frac{1}{v} = \frac{1}{30} - \frac{1}{50}$$

$$\frac{1}{v} = \frac{5-3}{150} = \frac{2}{150}$$

$$\therefore v = \frac{150}{2} = 75 \text{ cm}$$

$$\text{Now,} \quad m = \frac{I}{O} = \frac{v}{u}$$

$$\frac{I}{5} = \frac{75}{50}$$

$$I = \frac{75}{50} \times 5$$

$$= 7.5 \text{ cm}$$

∴ The image is formed 75 cm from the mirror and is 7.5 cm high.

Example 2

A convex mirror has a focal length of 30 cm. The object is placed at a distance of 90 cm from it. Find the position of the image.

Here $f = -30$ cm

$u = 90$ cm

$v = ?$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{-1}{30} = \frac{1}{90} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{-1}{30} - \frac{1}{90}$$

$$\frac{1}{v} = \frac{-3-1}{90} = \frac{-4}{90}$$

$$v = \frac{-90}{4} = -\ 22.5 \text{ cm}$$

The negative sign shows that the image is virtual.

5.3 Refraction

When a stick stands obliquely in water, it appears to be broken at the surface of the water in such a way that the part under water is bent upward. The bottom of a swimming pool always appears to be nearer the surface than it really is. This is due to the change in the speed of light which makes a ray of light bend as it passes from one medium to another. The bending of the path of a ray when light travels from one medium to another is known as *refraction of light.*

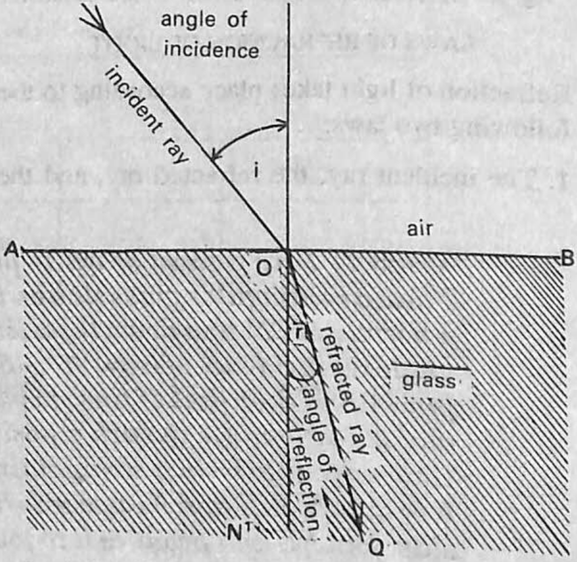


Fig. 5.9 (a) Refraction of light - rarer to denser medium

Thus if a ray PO travels from a rarer medium (air) to a denser medium (glass), PO is the incident ray, incident at O on the surface of separation *AB* between air and glass. *OQ* is the refracted ray. The angle which the incident ray makes with the normal is the *angle of incidence i* and the angle which the refracted ray *OQ* makes with the normal *ON* is the *angle of refraction r*. If the ray of light travels from a rarer to a denser medium, it bends towards the normal, and if it travels from glass to air, i.e., from a denser to a rarer medium, it bends away from the normal (Fig. 5.9 a and b).

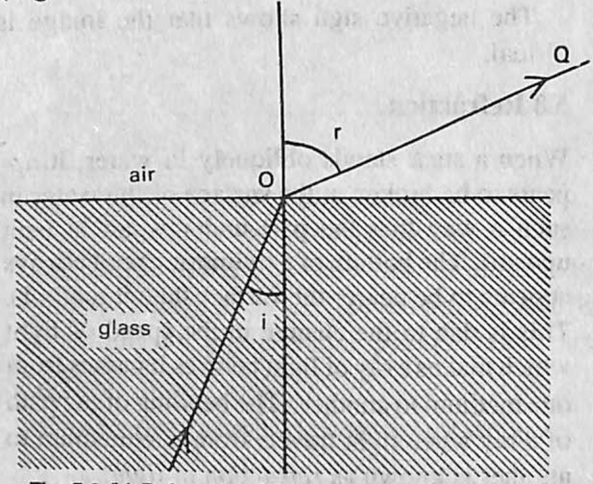


Fig. 5.9 (b) Refraction of light - denser to rarer medium

LAWS OF REFRACTION OF LIGHT

Refraction of light takes place according to the following two laws:

1. The incident ray, the refracted ray, and the normal at the point of incidence will lie in the same plane.
2. The sine of the angle of incidence bears a constant ratio to the sine of the angle of refraction and this constant depends upon the two media and upon the nature of the light.

or $$\frac{\sin i}{\sin r} = \text{constant}$$

This constant μ (pronounced as 'mew') is called the refractive index of the second medium with respect to the first. If the first medium is air or vacuum, the ratio $\frac{\sin i}{\sin r}$ is called the refractive index of the second medium. The second law of refraction is also called *Snell's law*.

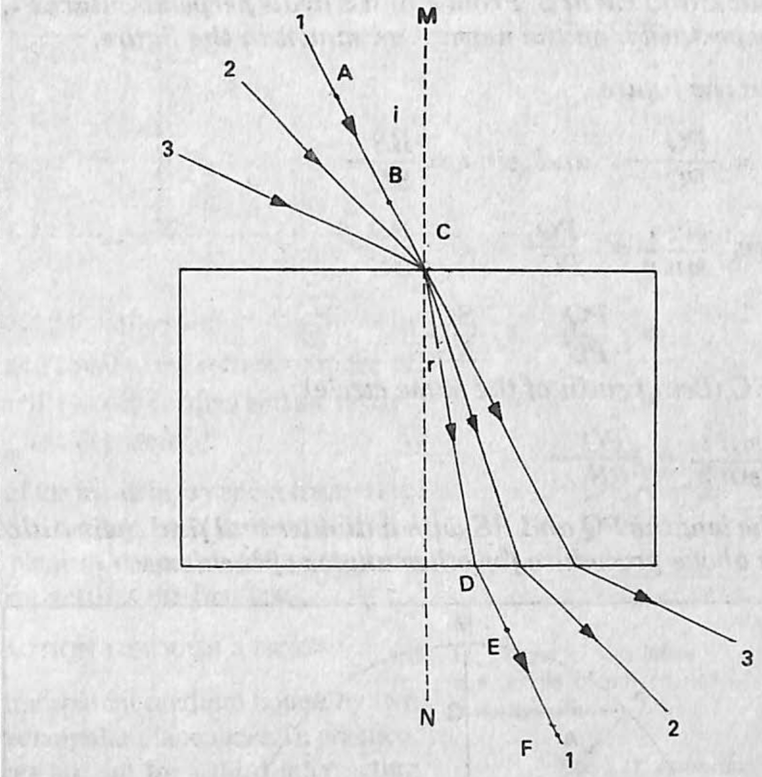
For example, if light passes from air to water this ratio is found to be 1.334 for yellow light. In other words, the refractive index of water is 1.334 for yellow light.

Note: The refractive index of the first medium (air) to the second glass) is

$$\frac{1}{\mu} = \frac{\sin i}{\sin r}$$

Verification of the laws of refraction : The laws of refraction may be verified in the laboratory.

Activity 7 : *Take a sheet of white paper and fix it on a drawing board. Place a rectangular glass slab on the paper and draw its outline. Draw a normal MCN and draw three lines to represent incident rays making angles of incidence of (say) 25°, 45°, 65°. Replace the slab and stick two pins A and B on the 25° line. Look through the opposite face of the block and place your eye in such a position that A and B seen through the slab, appear to be in a straight line with the eye. Place two pins E and F so that A, B, E and F appear to be in a straight line. Remove the glass slab, join FE and produce it to touch the slab at D. Join CD. AB is the incident ray, CD is the refracted ray and EF is the emergent ray. Measure the angle of refraction ($\angle NCD = r$) corresponding to the angle of incidence ($\angle ACM = i$) which is 25°. Repeat the experiment for the 45° and 65° angles of incidence and tabulate the readings.*



Verification of the laws of refraction

Sl. No.	i	r	$\sin i$	$\sin r$	$\frac{\sin i}{\sin r}$

Find the values of sin i and sin r from the logarithmic tables, and determine their ratios.

It will be found that the values in the last column are constant. This verifies the second law. Also, the ratio gives the value of the refractive index of glass with respect to air. So, apart from verifying the laws, this method is also used to determine the refractive index of glass with respect to air.

The law can also be verified without measuring the angles of incidence and refraction. This method was used by Snell.

Activity 8: *With C as centre and any convenient radius draw a circle cutting AB at P and EF at S. From P and S draw perpendiculars PQ and RS, respectively, on the normal as shown in the figure.*

Referring to the figure

$$\sin i = \frac{PQ}{PC} \quad \text{and} \quad \sin r = \frac{RS}{SC}$$

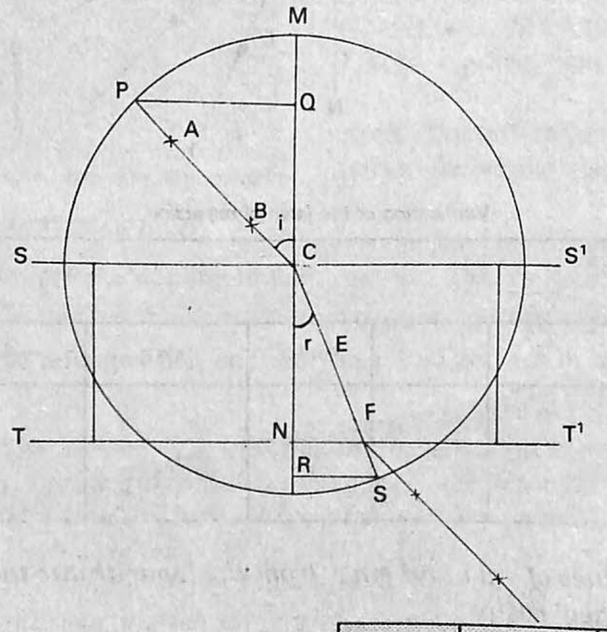
$$\text{Therefore,} \quad \frac{\sin i}{\sin r} = \frac{PQ}{PC} \div \frac{RS}{SC}$$

$$= \frac{PQ}{PC} \times \frac{SC}{RS}$$

but PC = SC (being radii of the same circle).

$$\text{Hence,} \quad \frac{\sin i}{\sin r} = \frac{PQ}{RS}$$

Measure the lengths PQ and RS with a divider and find their ratio. Repeat the above procedure for other angles of incidence.



PQ	RS	$\frac{PQ}{RS}$

Snell's method

Sl. No.	PQ	RS	$\frac{\sin i}{\sin r} = \frac{PQ}{RS}$

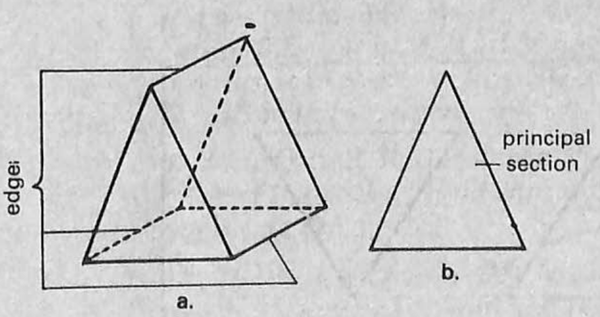
It will be found that the value of $\frac{PQ}{RS}$ will be a constant and equal to the refractive index of glass. Thus Snell's law is verified and the refractive index of glass determined.

The traces of the incident ray and refracted ray lie on the plane of the paper and the normal is also drawn on the plane of the paper. Hence they are coplanar, which verifies the first law.

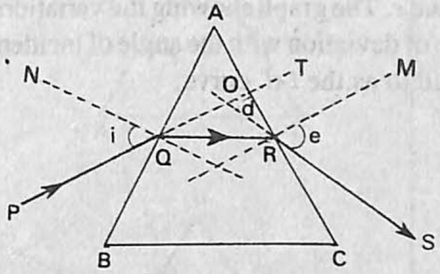
REFRACTION THROUGH A PRISM

A *prism* is a transparent medium bound by two intersecting rectangular plane faces. In practice, these two faces are cut by a third intersecting rectangular plane.

The lines along which any two of the rectangular faces meet are called the *edges* of the prism. The three edges of the prism are parallel to one another. The triangular section of the prism perpendicular to the edges is called its *principal section*. When we consider refraction through a prism, we assume that the ray lies in the principal plane.



5.10 Prism



i = angle of incidence
e = angle of emergence
d = deviation

Fig. 5.11 Refraction through a prism

The face of the prism on which a ray of light is incident is called the *incident face* and the face from which the ray emerges is called the *emergent face*. The third face is called the *base* of the prism. The angle between the incident and the emergent faces is called the *refracting angle*, or simply the *angle* of the prism.

In the figure, *ABC* is the principal section of a prism. *AB* and *AC* are the refracting edges. *PQ* is the incident ray and RS is the emergent ray. The angle *A* is the angle of the prism.

If a normal *QN* is drawn at the point of incidence, then $\angle NQP$ is called the angle of incidence. Another normal RM is drawn at the point of emergence. $\angle MRS$ is the angle of emergence. If the incident ray and the emergent ray are produced they meet at *O*. $\angle TOR$ between the incident and emergent rays is called the *angle of deviation d*.

For a prism of given refracting angle, the deviation suffered by a ray depends upon the angle of incidence. If the angle of incidence is gradually decreased from a large value, the angle of deviation also decreases, until for a particular angle of incidence, the deviation reaches a very small value, after which it increases for a further decrease in the angle of incidence. The smallest value of the angle of deviation d is called *the angle of minimum deviation*. In this position, the angle of incidence i is equal to the angle of emergence e. The graph showing the variation of the angle of deviation with the angle of incidence is referred to as the *i-d* curve.

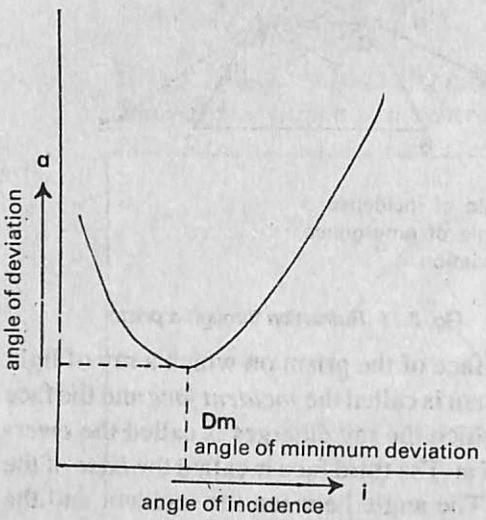


Fig. 5.12 i-d graph

NEWTON'S EXPERIMENT

In 1666, Sir Isaac Newton showed that sunlight consists of seven colours. A beam of sunlight was passed through a round hole in one wall of a dark room and formed a white image on the opposite wall. He placed a triangular prism in the path of the beam. A spectrum of seven colours formed on the wall (Fig. 5.13). It was not in the same position as the original white image. The red colour was deviated least from the position of the white image and the violet colour was deviated most.

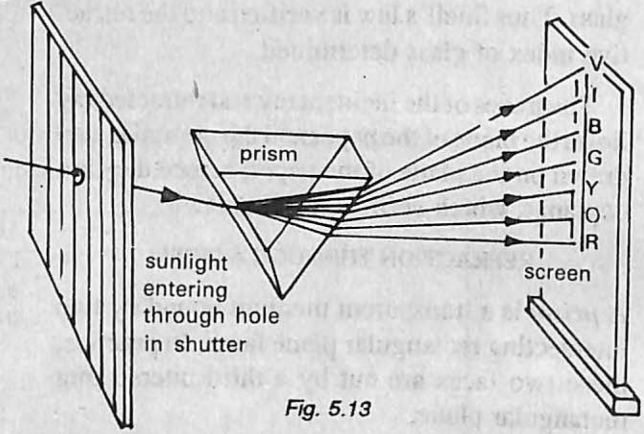
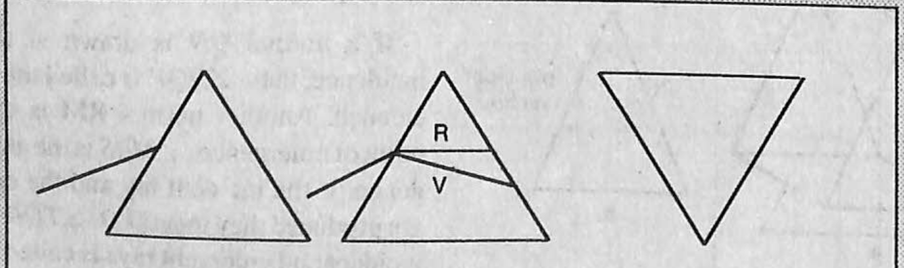


Fig. 5.13

Newton concluded that *white light is a mixture of seven coloured lights. Dispersion is the splitting up of white light into different colours by refraction.* Red light is refracted least and violet light most because the speed of red light in glass is faster than that of violet light.

Activity 9 : *Complete the following diagrams to show the dispersion of light.*



Activity 10: *To study deviation through a prism.*

Apparatus required: A glass prism, drawing board, tack pins, some paper pins, geometrical instruments.

Method 1. Fix a sheet of white paper to the board by means of the tack pins.

2. Place the prism on the sheet of paper with its refracting faces vertical.

*3. Draw the outline **ABC** of the prism on the paper.*

*4. Remove the prism and with a protractor draw a normal **NQ** to **AB**.*

*5. Using a protractor, draw a line **PQ** making an angle of 30° with the normal.*

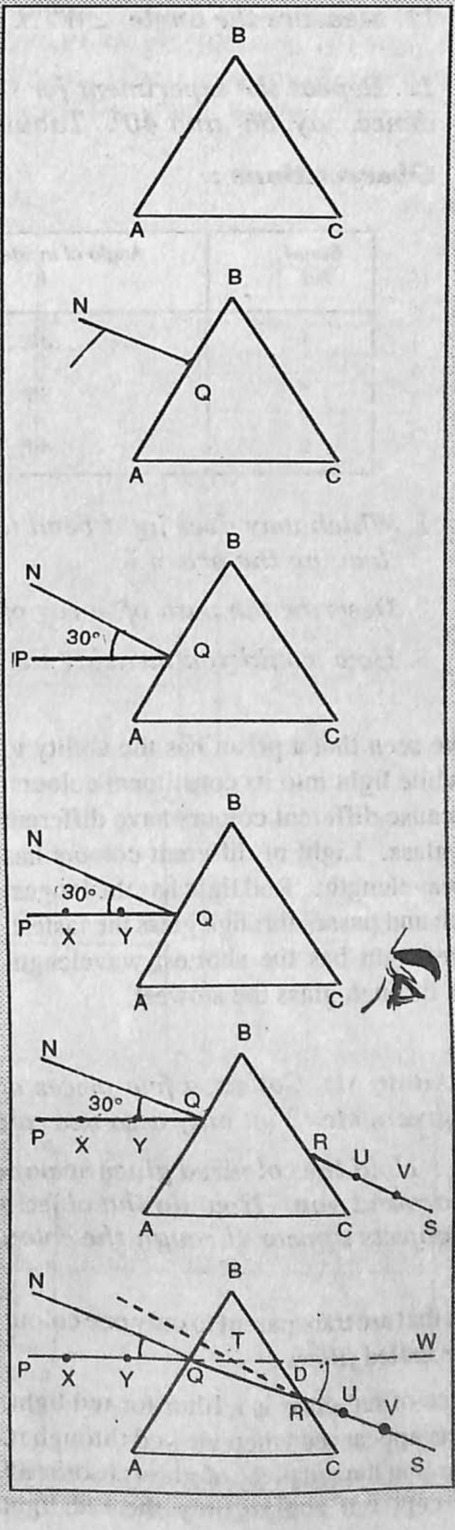
*6. Place two pins **X** and **Y** on the line **PQ**, which represents the incident ray and view **X** and **Y** through the face **BC**.*

*7. Now place two other pins **U** and **V** in front of **BC** so that the image of **X** and **Y** and the pins **U** and **V** appear to be in a straight line.*

*8. Remove the prism and the pins. Put pencil dots on the marks made by the pins. Join **U** and **V** and produce it to meet the line **BC** at **R**. **RS** is the emergent ray.*

*9. Join **Q** and **R** to obtain the trace of the path of light through the prism **QR**.*

*10. Produce **PQ** and **RS** backwards to meet at **T** and get the angle of deviation **D** = ∠**WTS**.*



11. Measure the angle ∠WTS.

12. Repeat the experiment for two other values of angle of incidence, say, 35° and 40°. Tabulate your readings as follows —

Observations :

Serial No.	Angle of incidence i	Angle of deviation D
1	30°	
2	35°	
3	40°	

1. *Which way does light bend (a) on entering the prism ? (b) On leaving the prism ?*
2. *Describe the path of a ray of light through the prism .*
3. *How would you measure the angle of emergence in each case?*

We have seen that a prism has the ability to disperse white light into its constituent colours. This is because different colours have different speeds in glass. Light of different colours has different wavelengths. Red light has the longest wavelength and passes through glass the fastest, while violet light has the shortest wavelength and passes through glass the slowest.

Colour plays an important role in our lives, and the study of coloured pigments and coloured lights is vast.

We will consider here, a few facts relating to coloured lights.

Transparent objects are able to absorb or subtract certain colours from white light.

Activity 11: *Collect a few pieces of coloured glass such as red, blue, green, etc. You may also use coloured cellophane paper instead.*

Hold the coloured glass or paper before your eyes and view objects around you. How do the objects appear? Why? How do coloured objects appear through the coloured glass of a particular colour?

Objects that are transparent to only one colour of light are called *filters*.

The piece of red glass is a filter for red light, if all objects appear red when viewed through it. This means that the red piece of glass absorbs all colours except red and so only the red light reflected from the objects reaches our eyes. However, all filters may not be transparent to only one colour. In fact the red filter allows a little orange to pass through it also, but the general appearance is red. A yellow filter allows green, yellow and orange light to pass through it while a blue filter allows violet, blue and green light to pass through it. Hence, the combination of a yellow and a blue filter will result in a green filter. Similarly, the combination of a red and yellow filter will result in an orange filter. This method of allowing light of certain colour or colours to pass through is called *subtraction theory*. The above paragraph will be made clearer from the following diagrams.

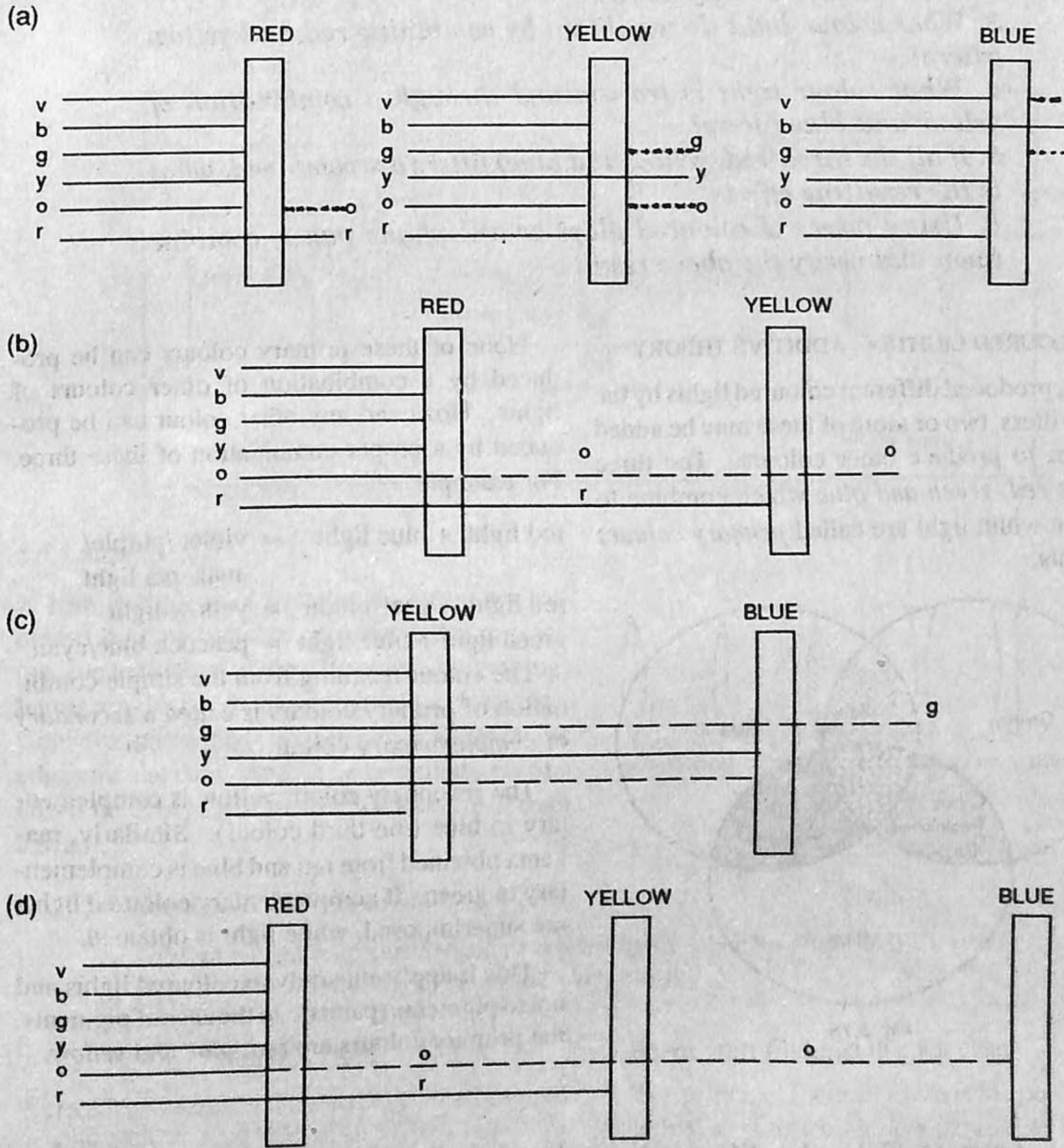


Fig. 5.14 Filters

Subtractive theory of colours :

(a) Red, yellow and blue filters
(b) Combination of red and yellow filters
(c) Combination of yellow and blue filters
(d) Combination of all three

Activity 12: *Study the diagrams on filters and answer the following questions.*

1. *What colours do each of the following filters transmit (i) red (ii) yellow (iii) blue ?*
2. *What colours do they absorb?*
3. *What colour light do we obtain by combining red and yellow filters?*
4. *What colour light is transmitted through a combination of yellow and blue filters?*
5. *If all the three (red, yellow and blue) filters are combined, what is the resulting effect?*
6. *Using pieces of coloured glass or cellophane paper, combine them and verify the above results.*

COLOURED LIGHTS — ADDITIVE THEORY

Having produced different coloured lights by the use of filters, two or more of these may be added together to produce other colours. The three colours *red, green and blue* which combine to produce white light are called *primary colours* for lights.

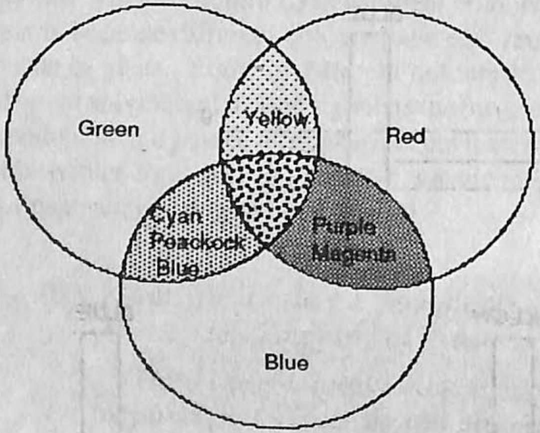


Fig. 5.15

None of these primary colours can be produced by a combination of other colours of lights. However, any other colour can be produced by a proper combination of these three. For example:

red light + blue light = violet /purple/ magenta light
red light + green light = yellow light
green light + blue light = peacock blue/cyan

The colour resulting from the simple combination of primary colours is called a *secondary* or *complementary* colour.

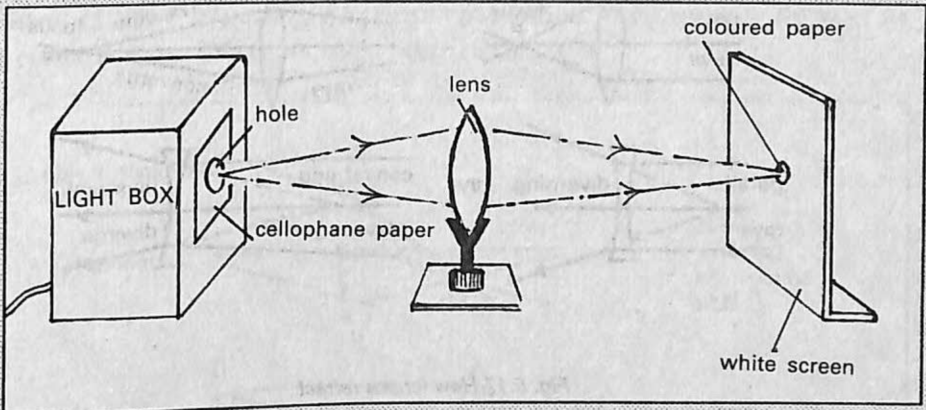
The secondary colour yellow is complementary to blue (the third colour). Similarly, magenta obtained from red and blue is complementary to green. If complementary coloured lights are superimposed, white light is obtained.

This is applicable only to coloured lights and not to pigments (paints). In the case of pigments, the primary colours are *red, blue* and *yellow*.

Activity 13: *Take a box fitted with an electric bulb and cover the face with cellophane paper of different colours. Combine the papers of different colours and allow the light from the light box to fall on a convex lens and then on to a white screen.*

Study the colours obtained on the screen for

1. red light.
2. blue light.
3. green light.
4. red + blue light.
5. red + green light.
6. green + blue light.



5.5 Lenses

A lens is a piece of transparent substance enclosed by two surfaces, one spherical and the other spherical or plane. Convex (converging) lenses are thicker at the centre than at the edges. Concave (diverging) lenses are thicker at the edges than at the centre. The principal axis of a lens is the line passing through the centre of each surface.

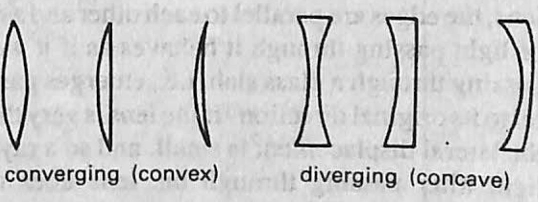


Fig. 5.16 Lenses

Activity 14: Concave lens

Look through a concave lens at a nearby object and then at a distant object. What can you say about the image?

CONVEX LENS

1. Hold a convex lens close to the printed page of a book.
2. Slowly increase the distance between the lens and book (object distance).
3. Look at a distant object through a convex lens held at arm's length from your eyes. Write down your findings in each case.

The principal focus of a lens is the point on the principal axis to which rays parallel to the axis converge after refraction (convex lens) or from which the rays appear to diverge after refraction (concave lens). The focal length of a lens is the distance between the principal focus and the centre of the lens.

The principal focus of a convex lens is real because 1. the image formed at the focus can be seen on a screen, and 2. rays of light pass through it.

The principal focus of a concave lens is virtual. Thicker lenses refract light more and have shorter focal length than thinner ones. A lens has a principal focus on both sides. They are the same distance from the lens, which has only one focal length.

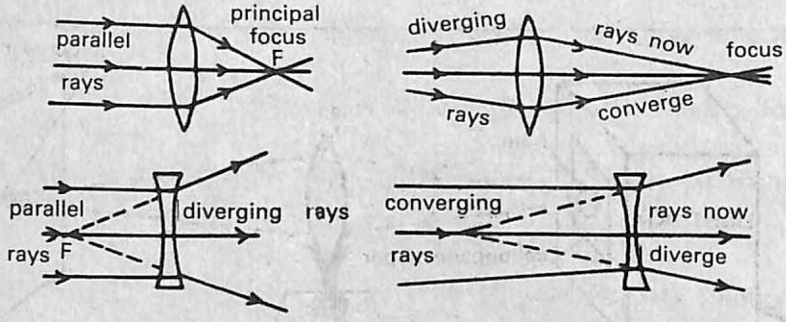


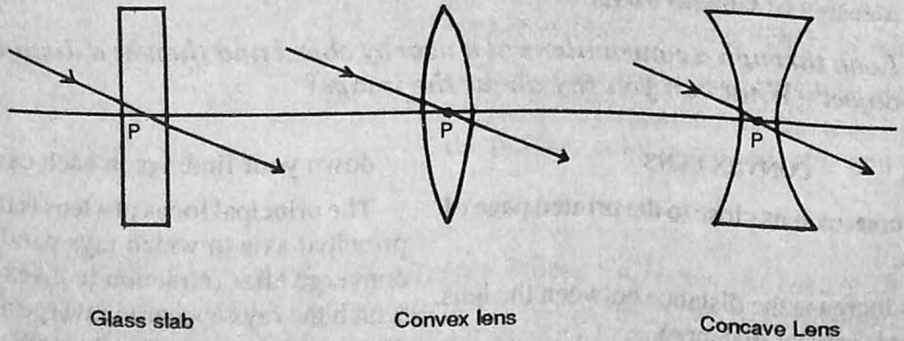
Fig. 5.17 How lenses refract

OPTIC CENTRE

For a very small region near the centre of the lens, the edges are parallel to each other and a ray of light passing through it behaves as if it were passing through a glass slab, i.e., emerges parallel to its original direction. If the lens is very thin, the lateral displacement is small, and so a ray of light after passing through the lens does not suffer any deviation or bending.

The point *P* inside the lens, where the ray cuts the principal axis is called the optic centre.

For thin lenses, the optic centre is at the centre of the lens itself. Hence, the *optic centre* of a lens is a point on the principal axis, through which a ray of light passing through does not change its path.



Glass slab

Convex lens

Concave Lens

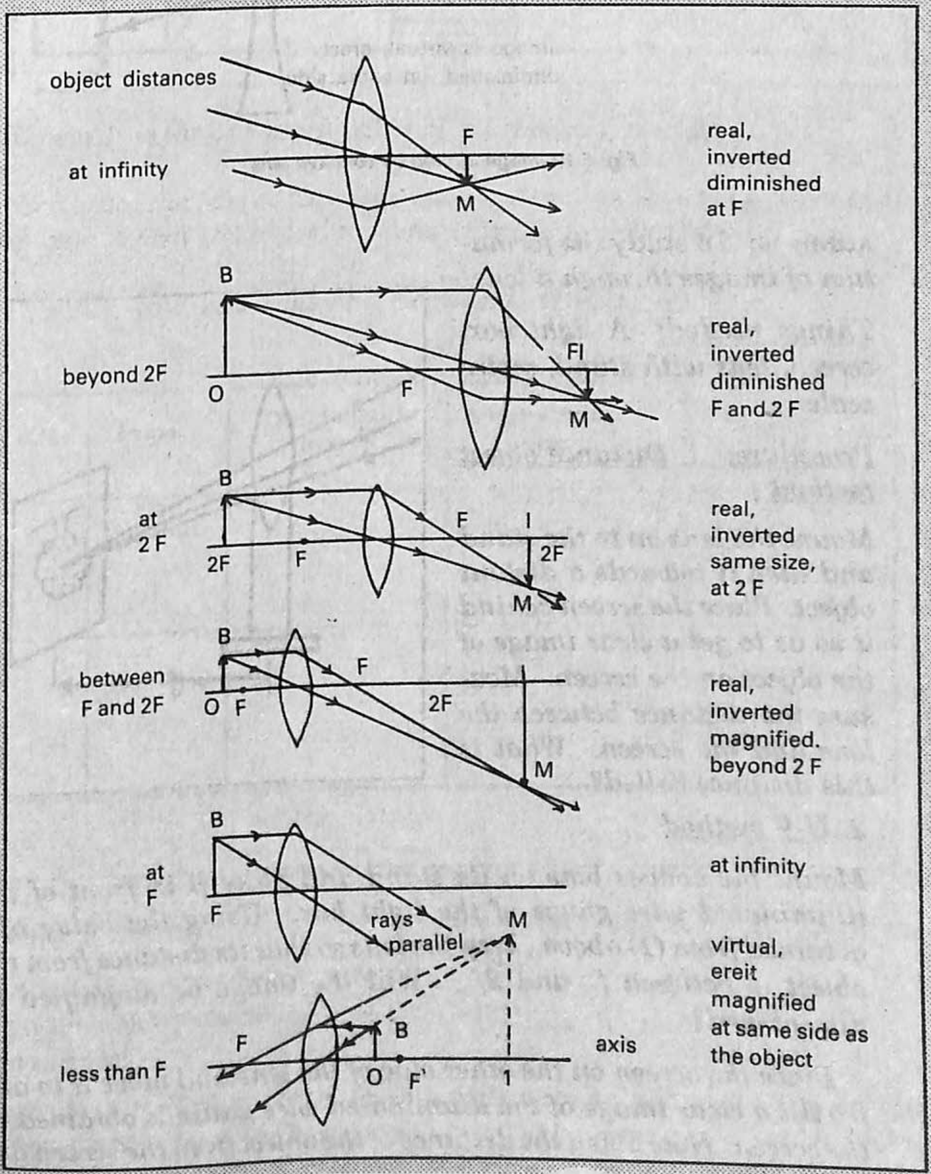
Fig. 5.18

FORMATION OF IMAGE BY LENSES

As in the case of mirrors, the following laws help us to find the position, nature and size of the image.

1. A ray passing through the principal axis, after refraction passes through the focus, or appears to diverge from the focus.
2. A ray through the optic centre does not change its path.
3. A ray through the focus emerges parallel to the principal axis.

Activity 15: *The following diagrams show how the image is formed in a convex lens. Draw them in your notebooks.*



Note that as the object distance becomes smaller, the image distance becomes larger. The image and object are always on the opposite sides of the lens except when the object distance is less than F (previous example).

IMAGES FORMED BY CONCAVE LENS

The image is always virtual, erect and diminished (Fig. 5.19).

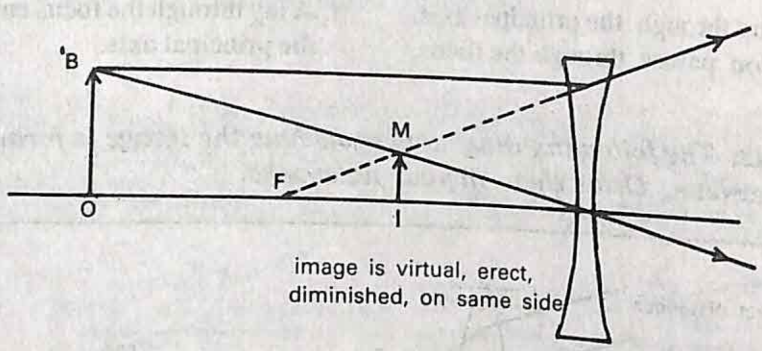
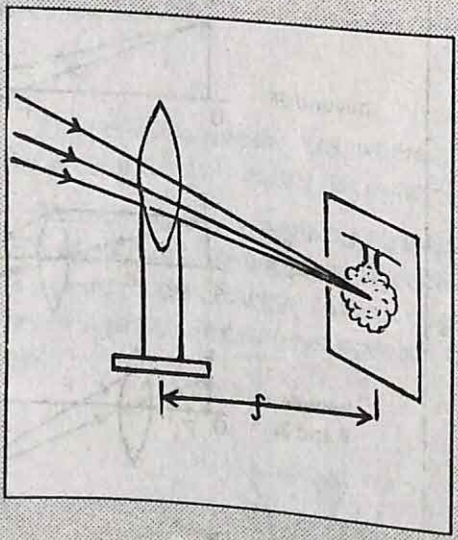


Fig. 5.19 Image formed by concave lens

Activity 16: *To study the formation of images through a lens.*



Things needed: *A light box, screen, lens with stand, metre scale.*

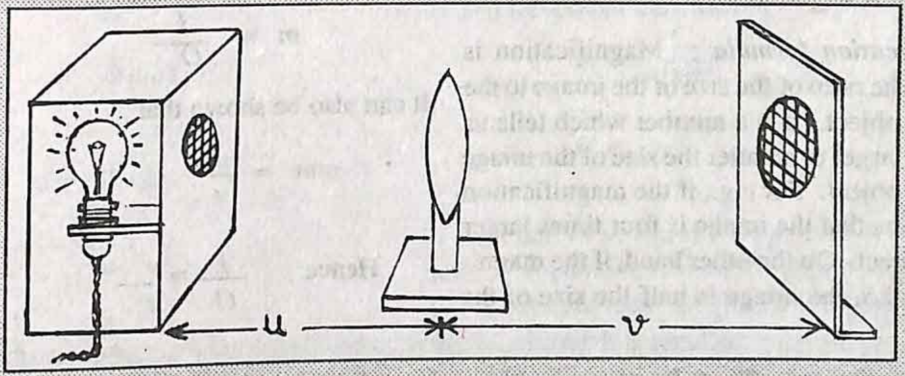
Procedure: *1. Distance object method ,*

Mount the lens on to the stand and turn it towards a distant object. Place the screen behind it so as to get a clear image of the object on the screen. Measure the distance between the lens and the screen. What is this distance called?

2. *U-V method*

Mount the convex lens on its stand and place it in front of the illuminated wire gauze of the light box. Using the value of f obtained from (1) above., keep the lens so that its distance from the object is between f and 2f . Will the image be magnified or diminished?

Place the screen on the other side of the lens and move it to and fro till a clear image of the illuminated wire gauze is obtained on the screen. Note down the distance of the object from the screen and *the distance of the image from the screen in the tabular form. Which position of the ray diagrams does this correspond to?*



Repeat this for one more value of u between f and 2f.

Now place the lens so that its distance from the object is greater than 2f and repeat the experiment for two more values of u.

Tabulate your readings and calculate the value of f.

S.N.	Image	Object distance u cms	Image distance v cm	$f = \frac{uv}{u+v}$ cm
1	Magnified			
2				
3	Diminished			
4				
				Mean 'f' = ... x 10^{-2} m

THE LENS FORMULAE

It is possible, by means of two formulae, to determine the position and characteristics of the image formed in a lens.

I. Distance formula : If the distance of the object from the lens is *u*, the distance of the image from the lens is *v*, and the focal length of the lens is *f*, then

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Here also, we follow the 'real is positive' convention for signs, i.e., all object and real image distances are taken to be positive and all virtual distances are taken to be negative. For example, the concave lens has a virtual focus and hence its focal length is negative.

II. Magnification formula : Magnification is defined as the ratio of the size of the image to the size of the object. It is a number which tells us how much larger or smaller the size of the image is than the object. For e.g., if the magnification is 4, it means that the image is four times larger than the object. On the other hand, if the magnification is 0.5, the image is half the size of the object. Putting it mathematically, if m is the magnification and I and O the size of the image and object, respectively, then

$$m = \frac{I}{O}$$

It can also be shown that

$$m = \frac{v}{u}$$

Hence ,
$$\frac{I}{O} = \frac{v}{u}$$

Activity 17: *The following problems have been worked out for you. Go through the solutions carefully and then work them out for yourself.*

1. *An object 5 cm tall is placed 30 cm from a convex lens whose focal length is 10 cm, find the position, nature and size of the image.*

(i) To calculate the position of the image

u = 30 cm
f = 10 cm
v = ?

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{10} = \frac{1}{30} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{30}$$

$$= \frac{3-1}{30}$$

$$= \frac{2}{30}$$

$$v = \frac{30}{2} = 15 \text{ cm.}$$

Is the image real or virtual? How do you know?

(ii) To calculate the size of the image
O = 5 cm v = 15 cm u = 30 cm I = ?

$$\frac{I}{O} = \frac{v}{u}$$

$$\frac{I}{5} = \frac{15}{30}$$

$$I = 5 \times \frac{15}{30}$$

$$= 2.5 \text{ cm.}$$

Is the image inverted or erect? Why?

2. *A concave lens has a focal length of 12 cm. An object 3 cm high is 36 cm from the lens. Determine the position and size of the image.*

(i) Position

f = −12 cm (the lens is concave)
u = 36 cm
v = ?

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$-\frac{1}{12} = \frac{1}{36} + \frac{1}{v}$$

$$\frac{1}{v} = -\frac{1}{12} - \frac{1}{36}$$

$$= \frac{-3-1}{36}$$

$$= \frac{-4}{36}$$

or $v = -9$ cms.

(ii) Size

$O = 3$ cm $\quad u = 36$ cm $\quad v = 9$ cm

$$\frac{I}{O} = \frac{v}{u}$$

$$\frac{I}{3} = \frac{9}{36}$$

$$I = \frac{3}{5} = 0.75 \text{ cms.}$$

Is the image real or virtual? inverted or erect?

Power of a lens

If the focal length of a lens is f metres, then the power of the lens is defined as the reciprocal of the focal length expressed in m.

$$P = \frac{1}{f}$$

hence, if f is expressed in cms then f cms = f/100 m and the power becomes

$$P = \frac{1}{f/100}$$

$$P = \frac{100}{f}$$

The unit of power is a *dioptre*. For a convex lens 'f' is positive and so the power is positive. For a concave lens, the power is negative since the focal length is negative.

Hence a lens with focal length 20 cm has a power

$$P = \frac{100}{20} = +5 \text{ dioptres}$$

and a concave lens of focal length 40 cms has a power

$$P = \frac{-100}{40} = -2.5 \text{ diopters}$$

Activity 18: ***Work out the following problem and check your answer with the solution.***

A object 10 cm from a convex lens gives an upright image 30 cm from the lens. Find the magnification and power of the lens.

$u = 10$ cms $\quad v = -30$ cms

The image distance is written with a minus sign. Why?

(i) Magnification

$$m = \frac{v}{u} = \frac{30}{10} = 3$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$= \frac{1}{10} - \frac{1}{30}$$

$$= \frac{3-1}{30}$$

$$= \frac{2}{30} = \frac{1}{15}$$

$$\therefore f = 15 \text{ cm.}$$

(ii) Since, f is in cm, power $P = \frac{100}{f} = \frac{100}{15}$

$$= \frac{20}{3} = 6.66$$

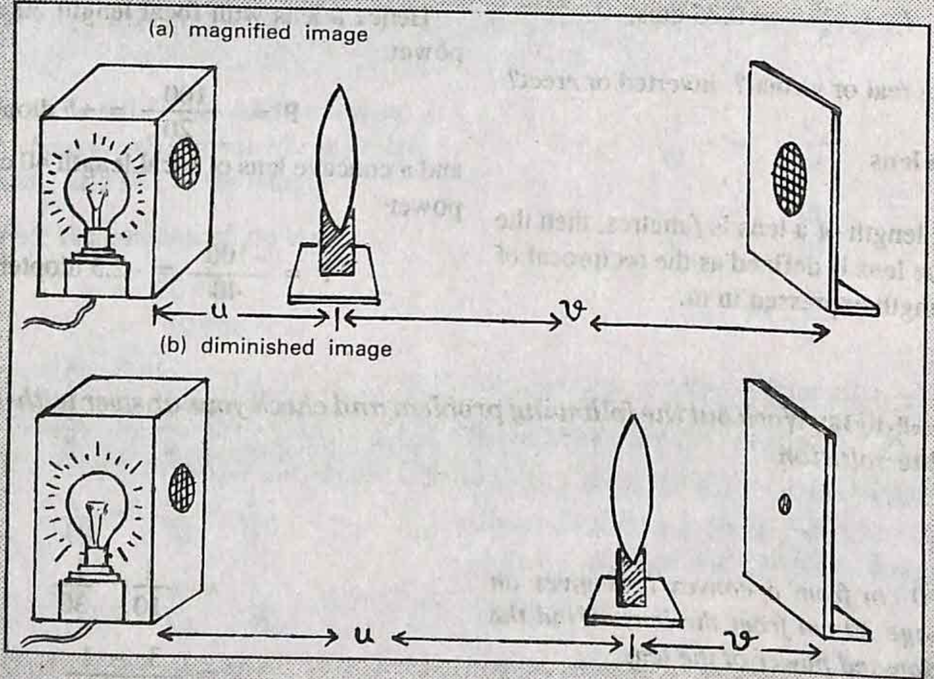
Magnification = 3, Power = +6.66 dioptres.

Activity 19: *To study the magnification produced by a lens.*

Apparatus required : Light box or candle and stand with wire gauze, convex lens with stand, white screen.

Procedure:

1. *Place the object, i.e., light box on one side of the lens and the screen on the other side.*
2. *Adjust the distance of the lens from the light box so that a magnified image is formed on the screen.*
3. *Move the screen to and fro till the magnified image is clear and not diffused.*
4. *Note down the distances u and v as shown below.*



5. *Repeat the above steps for one more position of object for magnified image and two more positions for diminished image.*
6. *Tabulate your readings as shown.*

S.N.	u	v	m = v/u
1			
2			
3			
4			

7. Calculate the magnification

$$m = \frac{v}{u}$$

for each case.

Conclusion: Is the magnification the same for all positions of the object?
When is it magnified?
When is it diminished?

Basic concepts

1. The image formed in plane mirrors, spherical mirrors and lenses are governed by certain laws.
2. The relation between the focal length and radius of a curved mirror is

$$r = 2f$$

3. The mirror formula for curved mirrors is

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

where f = focal length, u = object distance and v = image distance.

4. The magnification formula for curved mirrors is

$$\frac{I}{O} = \frac{v}{u}$$

5. Dispersion is the splitting up of white light into its constituent colours.
6. For coloured lights, the three colours red, blue and green which combine to give white light are called primary colours.
7. The colour obtained by mixing two primary colour lights is called a secondary colour or complementary colour.
8. Lens formulae

(i) Distance formula

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

where f = focal length, u = object distance and v = image distance.

(ii) Magnification formula

$$\frac{I}{O} = \frac{v}{u}$$

m = magnification, I = size of image O = size of object.

REVISION

I . Choose the correct answer.

1. The image in a plane mirror is
   a. real. b. inverted. c. in front of the mirror. d. virtual.
2. An object is placed in front of a convex mirror.
   a. The image is real. b. The image is inverted. c. The image is large. d. The image is diminished.
3. To obtain an erect magnified image in a convex lens, the object should be
   a. between the optic centre and F. b. between F and 2F. c. at 2F. d. beyond 2F.
4. In the determination of focal length of a concave mirror, the approximate method is
   a. graphical method. b. distant object method. c. u-v method. d. normal reflection method.
5. Light is incident from water to air at 30°. The angle of refraction is
   a. equal to 30°. b. less than 30°. c. greater than 30°.
6. The angle of deviation in a prism
   a. increases with angle of incidence. b. decreases with angle of incidence. c. both of the above.
   d. none of the above.

II. Fill in the blanks.

1. When the angle of incidence is 45°, the angle between the incident and reflected rays is ______.
2. The image in a plane mirror is (i) ________ . (ii) ________ . (iii) ________ . (iv) ________ .
3. The image in a ________ mirror is always diminished and virtual.
4. The central point on a mirror is called the ________ .
5. Images that cannot be formed on a screen are ________ images.
6. Images that can be formed on a screen are ________ images.
7. ________ mirrors are used as rear view mirrors in cars and buses.
8. A ray through the ________ ________ of a lens does not change its path.
9. When the object is at infinity the image is at the ________ .
10. Lenses which are bulging at the centre are called ________ lenses.
11. The size of image and object is the same at the ________ .
12. When light travels from a denser medium to a rarer medium, it bends ________ from the normal.
13. The incident ray, the refracted ray and the normal at the point of incidence all ________ ________ ________ .
14. The refractive index of a substance is the ratio of the sine of the angle of ________ to the sine of the angle of ________ .
15. In a curved mirror, magnification is the ratio of the size of ________ to the size of ________ .
16. The relation between the focal length, image distance 'v' and object distance 'u' is given by ________ .
17. ________ mirrors are used in ophthalmoscopes.
18. ________ mirrors are used in headlamps and searchlights.
19. Curved mirrors used as rear view mirrors in vehicles are ________ mirrors.
20. ________ mirrors are used as shaving mirrors.

III. State whether true or false.

1. A real image is formed in a plane mirror.
2. The image in a plane mirror is virtual.
3. The image in a plane mirror is formed in front of it.
4. When light travels from a denser medium to a rarer medium, it bends towards the normal.
5. For a curved mirror or a lens

$$\text{magnification} = \frac{\text{size of the object}}{\text{size of the image}}$$

6. The image in a convex mirror is always virtual, erect and diminished.
7. The relation for focal length is given by $f = uv/u + v$.
8. the u-v graph is a straight line.
9. For minimum deviation, the angle of incidence must be less than the angle of refraction.
10. For coloured lights, red, yellow and blue are the primary colours.
11. The primary colour lights combine to produce white light.
12. The secondary colour of two colours is the complement of the third.

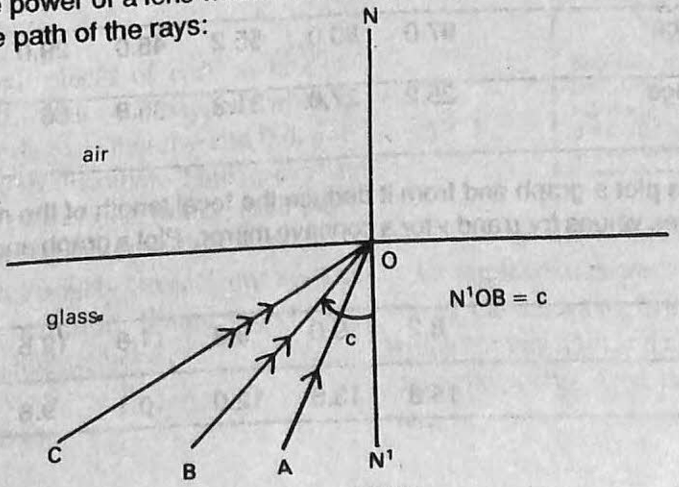
IV. Match the following.

1. plane mirror
2. convex lens
3. convex mirror
4. prism
5. glass slab
6. glass slab
7. concave lens

(a) minimum deviation
(b) diminished erect image
(c) secondary colours
(d) lateral inversion
(e) rear-view mirror
(f) primary colours
(g) Snell's law
(h) magnifying glass

V Problems:

1. Light is incident on a glass slab at 52°. If the angle of refraction is 30°, what is the refractive index of the glass slab? (Ans. 1.576)
2. Calculate the power of a lens whose focal length is .25 metres. (Ans. +4)
3. Complete the path of the rays:



4. An object is placed 40 cm in front of a concave mirror of focal length 15 cm. Find the position of the image. (Ans. 24 cm)
5. An object is placed on the principal axis of a convex mirror of focal length 10 cm. If the position of the object is 15 cm from the mirror find the position of the image. (Ans. 6 cm behind the mirror)
6. A concave mirror produces a real image 4 cm tall of an object 2.5 mm tall placed 5 cm from the mirror. Find the position of the image. (Ans. 80 cm in front of the mirror)
7. If the magnification of an object of height 10 cm is 0.5, what is the height of the image? (Ans. 5)
8. An object 4 cm high is placed 25 cm from a convex lens of focal length 10 cm. Find the position, size and nature of the image. (Ans. 16.7 cm, 2.7 cm, real)
9. An object 5 cm high is placed 20 cm from a concave lens of focal length 10 cm. Find the position, size and nature of the image. (Ans. –6.7 cm, 1.68, virtual)

VI. Answer the following questions.

1. How would you show by an experiment that the image in a plane mirror is as far behind the mirror as the object is in front of it.
2. Draw a diagram to show how the eye sees a point object in a plane mirror.
3. Draw a diagram to show how the eye sees an extended object in a plane mirror.
4. State the laws of refraction of light. What is meant by refractive index?
5. Describe a simple method of determining the refractive index of a rectangular glass block.
6. Draw a diagram to show how a ray of light passes through a glass prism. Label the diagram with the following:
   a. angle of the prism.
   b. base.
   c. angle of incidence.
   d. angle of emergence.
   e. angle of deviation.
   Also draw a diagram showing how the angle of deviation varies with the angle of incidence.
7. Describe an experiment to determine the focal length of a convex lens.
8. Describe an experiment to determine the magnifying power of a lens.
9. Describe an experiment to determine the radius of curvature of a concave mirror.
10. Describe how you would determine, as accurately as possible, the focal length of a concave mirror.
11. The following figures were obtained with a certain concave mirror.

Object distance *u* cm	97.0	80.0	55.2	45.0	29.0	24.4
Image distance *v* cm	25.2	27.0	31.3	35.8	66	108

Using these figures plot a graph and from it deduce the focal length of the mirror.

12. The table below gives values for *u* and *v* for a concave mirror. Plot a graph and calculate its focal length.

u in cm	8.2	9.0	9.8	11.6	12.5	14.2
v in cm	15.8	13.6	12.0	10.1	9.6	8.7

6. Sound

Wave motion - reflection - echoes - free and forced vibrations.

6.1 Wave motion

Sound is caused by bodies in vibration. The majority of musical instruments produce notes either by the vibration of stretched strings or by the vibration of air in pipes. These vibrations cause the air in the neighbourhood to vibrate, and this disturbance travels out in the form of waves. If you throw a stone into a pond, you will notice that a disturbance is created on the water surface. This disturbance appears in the form of ripples on the surface of water.

Place some small pieces of cork or bits of paper on water and watch what happens when a wave passes under them. They rise and fall, not together, but one after the other. Thus, we infer that when a wave passes over water, each particle never moves far from its position of rest, but vibrates, not simultaneously but each one a little later than the one before it. Sound waves can pass through a medium either as

1. transverse waves, or
2. longitudinal waves.

TRANSVERSE AND LONGITUDINAL WAVE MOTION

In transverse wave motion, the particles of the transmitting medium travel to and fro along paths perpendicular to the direction in which the wave moves (6.1a).

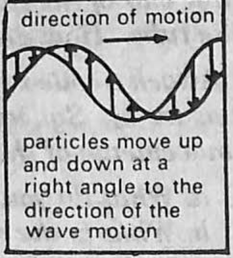

direction of motion
particles move up and down at a right angle to the direction of the wave motion

Fig. 6.1a Transverse wave motion

Examples of transverse wave motion are water waves, radiant waves in the ether of space, waves which convey light and heat energy, and electromagnetic waves used in wireless communication.

In longitudinal wave motion, the particles of the transmitting medium travel backwards and forwards in the path which is along the line that marks the direction in which the wave moves.

Sound travels as longitudinal waves, i.e., wave particles oscillate in the same direction as the wave travels. Owing to the longitudinal motion of the wave particles, sound waves consist of a series of *compressions* which is followed by *rarefractions.*

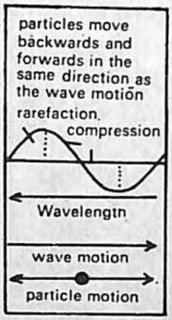
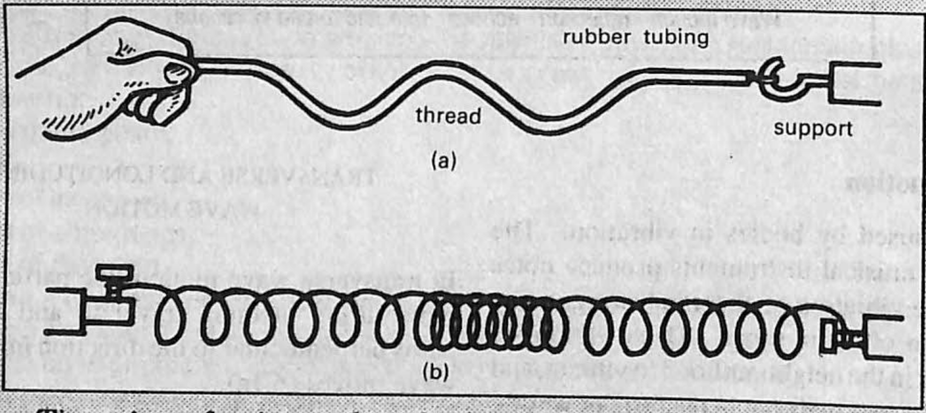

particles move backwards and forwards in the same direction as the wave motion
rarefaction
compression
Wavelengtn
wave motion
particle motion

Fig. 6.1b Longitudinal wave motion

Activity 1: ***To illustrate the different kinds of fundamental characteristics of wave motion.***

1. Tie one end of a rubber tubing to a support as shown in figure (a).



Tie a piece of string to the tube, leaving one end dangling. Vibrate the free end of the tube up and down with the hand. Note the effect on the tube. How does it vibrate?

2. Attach a coiled spring between two supports. Tie a piece of string to it as in (b). Squeeze several coils together and release them. Note the movements of the string.

1. a. What do you observe when the end of the tube is vibrated?
b. What is the direction of motion of the tubing with respect to its length?

2. a. What do you observe when you release the coils of the spring?
b. What is the direction of motion of the coils of spring relative to its length?

3. How does this activity help you understand the characteristics of transverse and longitudinal wave motion ?

Look carefully at Fig. 6.2 and try to recall and understand all the terms given below:

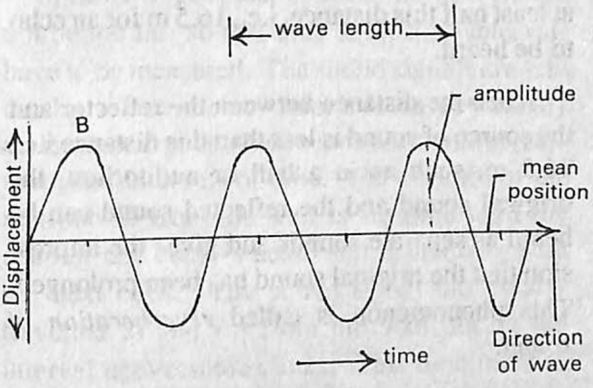


Fig. 6.2

Amplitude: The maximum displacement from the mean position, e.g., BB_1 or DD_1 is called an *amplitude*.

Particles at the same distance from their mean positions and which are moving in the same direction are said to be *in phase*, i.e., *P* and *Q* in Fig. 6.2. Particles such as *B* and *D* are said to be *out of phase*.

Wavelength: This is the distance between two particles in the same phase, i.e., the distance *FJ* or *DH* or *AE*, etc.

Period of vibration (T): The time taken for one complete vibration is called the period of vibration, i.e., the time taken by a particle in travelling from its mean position through its maximum displacement first in one direction and then in the other, finally returning to its mean position.

Frequency (n): This is the number of vibrations made in one second. The unit of frequency is the *hertz*.

Wave train: This indicates a succession of waves caused by continuous vibration of the source.

Velocity: The distance covered by the disturbance in one second is called the *velocity*. During one vibration, the disturbance travels a distance of one λ, therefore the distance travelled for

$$n \text{ vibrations} = n\,\lambda$$

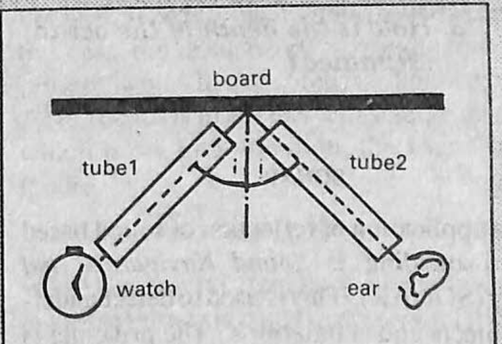
Since *n* vibrations take place in one sec., $n\,\lambda$ is the distance travelled in one second.

$$\text{or,} \quad v = n\,\lambda$$

6.2 Reflection — echoes

Activity 2: *Look at the following diagram which you may be familiar with and answer the following questions:*

1. *What does this experiment demonstrate ?*
2. *What is the purpose of tube 1?*
3. *What is the purpose of tube 2?*
4. *What happens at the surface of board AB ?*
5. *What can you say about the angle of inclination of tubes 1 and 2 ?*
6. *What conclusions can you draw from this experiment ?*
7. *What is the purpose of board CD ?*
8. *What will happen if the position of either tube is changed ?*



Reflection of sound

ECHOES

An echo is the repetition of sound caused by reflection from some distant obstacle. Thus, when a sound is produced before a distant hill or a row of buildings, an echo is generally heard.

It has been found that for an inarticulate sound which lasts for a very short interval of time, such as gun-fire, clapping of hands, cooing, etc., the sensation of sound persists in the ear for about one tenth of a second. Hence, our ears will be able to hear an echo only if the sound produced and its reflection reach the ear at least 1/10 of a second apart.

The velocity of sound in air is 330 m/s, i.e., sound travels 330 metres in one second. Therefore, the distance travelled by sound in 1/10 of a second = 33 m. So the reflecting surface must be at least half this distance, i.e., 16.5 m for an echo to be heard.

When the distance between the reflector and the source of sound is less than this distance,i.e., 16.5 m, such as in a hall or auditorium, the original sound and the reflected sound can be heard as separate sounds and gives the impression that the original sound has been prolonged. This phenomenon is called *reverberation of sound*.

Activity 3: *List some of the uses of reflection of sound.*

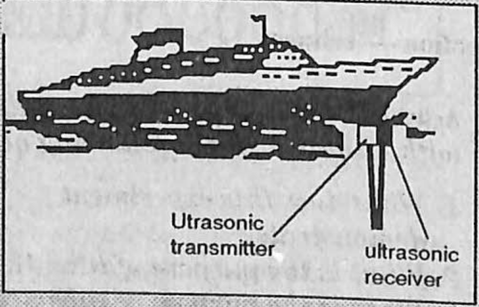
SOUND WHICH CANNOT BE HEARD

Only sound with a frequency between 16 hertz and 20,000 hertz (one vibration per second is called a hertz) can be heard by the human ear. Air vibrations with higher frequencies cannot be heard by the human ear. They are called *ultrasonic waves*.

With the help of crystals that can be made to vibrate electrically, ultrasonic waves up to 1000 MHz can be produced ($1\text{MHz} = 10^6\text{Hz}$). Ultrasonic waves have thousands of times more energy than normal sound waves.

Activity 3: *Look at this diagram about echo – sounding which you have learnt about earlier.*

1. *What is echo sounding?*
2. *What is it used for here?*
3. *How is the depth of the ocean estimated?*



SONAR

Another application of reflection of sound based on echo-sounding is *Sound Navigation and Ranging* (SONAR). This is used to detect underwater objects and submarines. The principle is the same as that of echo-sounding except that the transmitter and receiver are placed in a dome-shaped container which can rotate about a vertical axis. From the time taken between transmission and reception of the ultrasonic waves, the depth at which the submarine is located is determined. The angle of rotation of the dome gives the direction in which the submarine is travelling.

DETERMINATION OF VELOCITY OF SOUND BY ECHO-SOUNDING

If a sound signal is directed to a distant wall or obstacle, an echo will be received some time later. The sound travels twice the distance between the wall and the observer during this period.

In order to get clear echoes, the wall should not be too far so that only short time intervals have to be measured. The sound signals are sent out by a *metronome* which is an electrically maintained tapper which sends out sound signals at regular intervals of time. The distance of the metronome from the wall is adjusted until the echo of one click is heard simultaneously with the next click. The sound signal has clearly travelled to and fro from the wall during the interval between the clicks. This time interval can be measured accurately and so the velocity of sound can be calculated.

$$\text{velocity} = \frac{\text{distance travelled}}{\text{time taken}}$$

$$= \frac{2 \times \text{distance of metronome from the wall}}{\text{time}}$$

The velocity of sound in air at 0°C is 332 m/s.

6.3 Free and forced vibrations

FREE VIBRATIONS

When a body, capable of oscillating, is excited and left to itself, it will vibrate with a frequency of its own. This is called its *natural frequency*, which is the number of vibrations made in one second measured in hertz. The vibration of the body is called its *free vibration*. For example, when a tuning fork on a suitable stand is struck with a rubber hammer, and left to itself, the prongs of the fork are found to vibrate with a definite frequency of their own. This vibration is said to be the fork's free and natural vibration.

A pendulum, when disturbed from its position of rest and left to itself, will continue to swing to and fro with a free and natural frequency of its own.

FORCED VIBRATIONS

When a body, which is capable of vibration is made to vibrate with the natural frequency of another vibrating body, then its vibrations are known as *forced vibrations*.

If a vibrating fork is held in air, we do not usually hear any sound coming from the fork. But when the stem of the same vibrating fork is pressed against the top of a wooden table, the sound is clearly audible. In this case, the table top is forced to vibrate with the frequency of the tuning fork. The table top, being larger in size, sets a large amount of air into vibration, and this makes the sound audible. Here, the table is forced to vibrate with the natural frequency of the tuning fork.

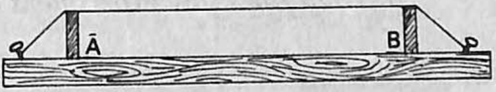


Fig. 6.3 Stretched string

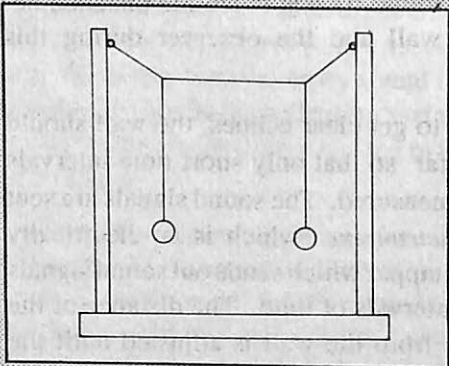
When a string which is stretched tightly is plucked, it will set a very small quantity of air into vibration, making a very feeble sound. But when the same string is stretched upon a board, and passed over two bridges *A* and *B*, as shown in Fig. 6.3, and plucked, a loud sound is heard. In this case, the string exerts a periodic force on the bridges, which in turn forces the board to vibrate. As the board is in contact with a large mass of air which is set into vibration, the sound heard is louder.

RESONANCE

When the natural frequency of the body being forced to vibrate is equal to the natural frequency of the vibrating body, the resulting vibration is said to be *resonance vibration* and the vibration is of maximum amplitude. Another name for resonant vibrations is *sympathetic vibrations*.

Activity 4: *Suspend two simple pendulums of equal length from a slightly stretched horizontal cord. Pull one pendulum aside and allow it to oscillate.*

1. *What do you observe?*
2. *What does this experiment demonstrate?*
3. *Give reasons for your answer.*

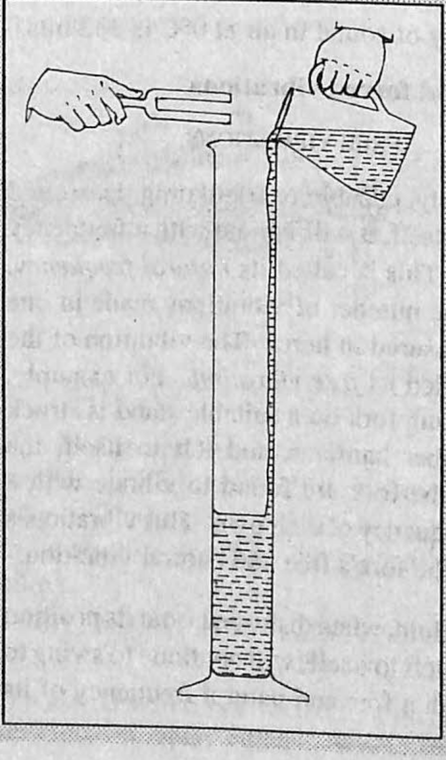


Activity 5: *Stretch a wire over two bridges of a sound box. Strike a tuning fork on a rubber pad and place it on the sound box. Adjust the positions of the two bridges so that a paper rider placed in the centre is thrown off.*

1. *Why do you hear a loud sound when the tuning fork is placed on the sound box?*
2. *Why does the paper rider fly off?*
3. *What does this experiment demonstrate?*

Activity 6: *Set a tuning fork into vibration and hold it near the open end of a fairly tall glass cylinder. The sound emitted is very faint. Pour water slowly into the cylinder until the sound becomes louder.*

1. *Why is the sound very faint except at a certain level?*
2. *What does this experiment demonstrate?*



Basic concepts

1. Sound waves pass through a medium as either transverse waves or longitudinal waves.
2. Transverse waves consist of crests and troughs while longitudinal waves consist of a series of compressions and rarefractions.
   — In transverse wave motion, the particles of the medium travel to and fro along paths *perpendicular* to the direction of propagation of the wave.
   — In longitudinal wave motion, the particles of the medium travel backwards and forwards *along* the direction of propagation of the wave.
3. Wavelength is the distance between two particles in the same phase (λ).
4. Frequency is the number of vibrations made in one second (n).
5. The velocity of the wave is given by
   $$v = n\lambda$$
6. An echo is the repetition of sound caused by reflection from some distant obstacle.
7. Sound waves having frequencies greater than 20 KHz are called ultrasonic waves.
8. SONAR means sound navigation and ranging.
9. When the natural frequency of the body being forced to vibrate is equal to the natural frequency of the vibrating body, the resulting vibration is said to be resonance vibration.

REVISION

I. Fill in the blanks:

1. In transverse waves, the particles vibrate ________ to the direction of propagation.
2. In longitudinal waves, the particles vibrate ________ to the direction of propagation of the waves.
3. Longitudinal waves travel as ________ and ________ .
4. Transverse waves travel as ________ and ________ .
5. The maximum displacement from the mean position is called ________ .
6. The unit of frequency is ________ .
7. A ________ is the repetition of sound caused by reflection from some distant obstacle.
8. Sound waves having frequencies greater than 20 KHz are called ________ .

II. Choose the correct answer.

1. A wavelength is
   a. the distance travelled by the wave. b. the maximum displacement. c. the distance between two crests. d. the distance between a crest and a trough.
2. If a tuning fork *A* is allowed to vibrate near a tuning fork *B* of the same frequency, the vibrations of *B* are said to be
   a. resonant. b. free. c. forced. d. none of the above.

III. State whether true or false:

1. Transverse waves consist of rarefractions and compressions.
2. The period of vibration is the time taken for one complete vibration.
3. Amplitude is the distance between one crest and one trough.
4. The relation between velocity and wavelength is $\lambda = v/n$.
5. Echo sounding is based on reflection of sound.
6. Ultrasonics are sound waves of frequencies above 20 Hz.
7. When a stretched string is plucked, its vibrations are forced vibrations.
8. The vibrations of a simple pendulum are free vibrations.

IV. Answer the following questions:

1. Describe an experiment to demonstrate
   (a) transverse waves. (b) longitudinal waves.
2. Define the terms amplitude, phase, wavelength, period of vibration, frequency and velocity.
3. Explain what is meant by reverberation of sound?
4. Write a note on echo-sounding.
5. Explain the use of SONAR.
6. How is the velocity of sound determined by echo-sounding?

V. Match the following:

1. free vibration	(a)	$n < 20$ KHz
2. wave length	(b)	$\frac{\text{distance travelled}}{\text{time taken}}$
3. ultrasonic waves	(c)	frequency of its own
	(d)	$n > 20$ KHz
	(e)	distance between two particles in phase

7. Magnetism - I

Magnetic field - magnetic strength - plotting lines of induction - magnetic moment

MAGNETIC FIELD

When iron filings are sprinkled around a bar magnet on a sheet of paper, and the paper is tapped, the filings settle in a definite pattern. This shows that the magnet exerts a magnetic force in the region around it. The space surrounding a magnet or a current-carrying conductor in which the magnetic force is exerted is called the *magnetic field.*

It will also be noticed that the iron filings adhere most at regions near the poles of the magnet, where the attracting power of the magnet is greatest. A pivoted magnetic needle will come to rest in the north-south direction. The pole turned towards the north is called the *north-seeking* pole or *north pole*. The pole turned towards the south is called the *south pole*.

MAGNETIC FIELD STRENGTH AND MAGNETIC POLE STRENGTH

The definitions of magnetic field strength and magnetic pole strength may be obtained from Coulomb's Inverse Square Law, which states that *the force between two poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them.*

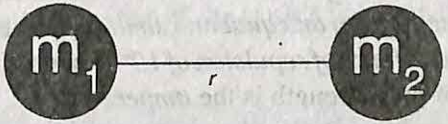


Fig. 7.1

Let F be the force between two poles of strength m_1 and m_2 separated by a distance r. Then, by Coulomb's law,

$$F \propto m_1 m_2$$

$$\text{and } F \propto \frac{1}{r^2}$$

Combining both, we have

$$F \propto \frac{m_1 m_2}{r^2}$$

$$F = K \frac{m_1 m_2}{r^2}$$

where K is the constant of proportionality.

In the SI system of units, $K = \frac{\mu_0}{4\pi}$ where μ_0 is the permeability constant of free space or vacuum and has a value of $4\pi \times 10^{-7}$ henry/metre.

Hence,

$$F = \frac{\mu_0}{4\pi} \times \frac{m_1 m_2}{r^2}$$

On the basis of this equation the unit pole strength can be defined.

If $m_1 = m_2 = 1$ and $r = 1$ metre, then

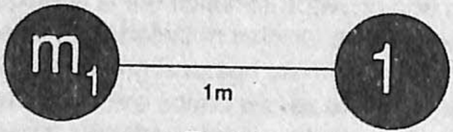


Fig. 7.2

$$F = \frac{4\pi \times 10^{-7}}{4\pi} = 10^{-7}\,\text{N}$$

Therefore, the unit magnetic pole is *that pole which, when kept in air or vacuum at a distance of 1 metre from an equal and similar pole, experiences a force of repulsion of* 10^{-7} *newtons.* The unit of pole strength is the *ampere metre.*

If, in the above expression, $m_1 = m$ and $m_2 = 1$, then the force

$$F = \frac{\mu_0}{4\pi} \times \frac{m \times 1}{r^2}$$

This force is called the *magnetic induction B.*

$$\therefore B = \frac{\mu_0}{4\pi}\ \frac{m}{r^2}$$

Magnetic induction at a point in a magnetic field *is the force experienced by a unit north pole when placed at that point.* This is a measure of the strength of the magnetic field. The unit of magnetic induction is the *tesla.*

MAPPING OF MAGNETIC FIELDS

The space around a magnet in which its magnetic influence is felt is called the *magnetic field.* A curve may be drawn in a magnetic field in such a manner that the tangent to it at any point is parallel to the direction of the field at that point. Such curves are called *lines of magnetic induction.* They start at the north pole and end at the south pole. They do not intersect each other. If the magnetic field is uniform, the lines of magnetic induction are parallel to each other.

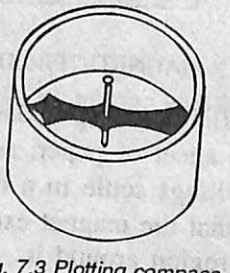
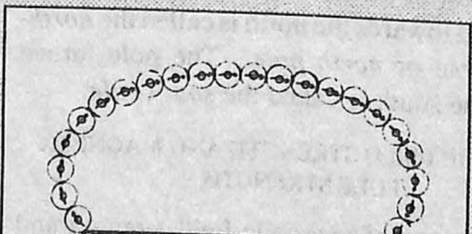


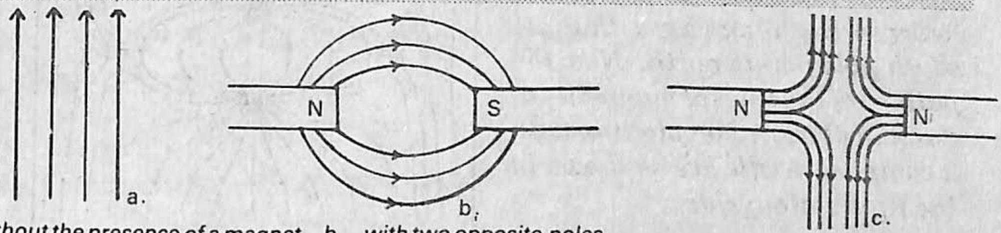
Fig. 7.3 Plotting compass

A magnetic field can be easily mapped using a compass needle. The compass needle used for this purpose is shown in the figure. It is a very small magnet pivoted on sharp bearings, placed inside a flat cylindrical brass case with glass covers at the top and bottom.

Activity 1: *To plot the lines of magnetic induction, place a bar magnet on a sheet of paper, and mark its outline. Place a compass needle close to the north pole of the bar magnet. When the needle comes to rest, mark out the position of the needle with two dots against the two poles of the needle. Move the needle until*



the south pole of the needle in the second position lies above the dot made by the north pole in the previous position. When the needle comes to rest again, mark another point in front of the north pole. Continue this process till the south pole of the bar magnet is reached. The line joining the successive dots gives the line of magnetic induction. In this way, the whole field of the magnet in the plane of the paper may be mapped out.



a. without the presence of a magnet b. with two opposite poles

Fig. 7.4 Lines of magnetic induction

c. with two similar poles

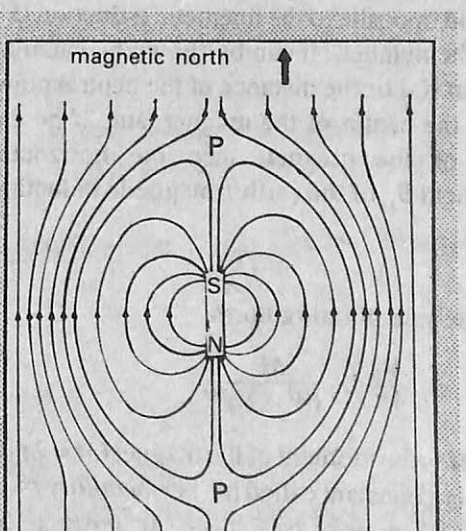
If the lines of magnetic induction are plotted without the presence of any magnet, a series of parallel lines are obtained. The lines of induction obtained when two opposite poles (b) and similar poles (c) are placed near each other are shown in Fig. 7.4. In the cases described so far, we have not considered the action of the field due to the earth. Since the field of the earth is very weak, its influence is not felt in the regions close to the poles. At a distance from the poles, the field due to the magnet becomes comparable with the field due to the earth. The pattern of the lines of induction of a magnet is really due to the combined effect of the earth's field and that due to the magnet.

Activity 2: *Plot a few lines of magnetic induction to demonstrate (a), (b) and (c) as explained above : (i) using iron filings. (ii) using a compass needle.*

Activity 3: To plot the magnetic field of a bar magnet

1. North pole pointing north

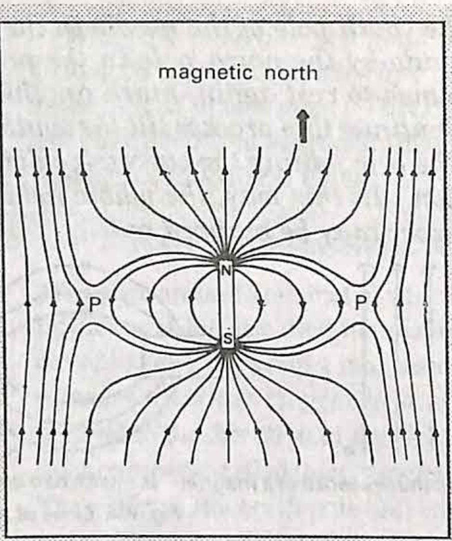
Take a sheet of white paper and draw a line across its centre parallel to one of the edges. Place a compass needle on this line and rotate the sheet of paper until the magnetic needle lies exactly along the line. In this position, secure the corners of the paper to the table, and place a bar magnet on the line with its north pole pointing north, which you have marked on the paper. Bring the



compass needle near the north pole of the magnet and draw the lines of magnetic induction. The lines of induction will assume the pattern as shown in the figure.

2. South pole pointing north

Reverse the magnet so that its south pole points north. Now the pattern of the lines of magnetic induction obtained on plotting with a compass needle are as shown in the figure alongside.



It can be seen that no lines of induction pass through certain points marked *P*. At such points, the magnetic induction due to the magnet is exactly equal and opposite to the magnetic induction due to the earth's magnetic field, i.e., the resultant magnetic induction at these points is zero. Such points in a magnetic field where the resultant magnetic induction is zero are called *neutral points* or *null points*. At these points, the magnetic induction due to the horizontal component of the earth's magnetic field (B) is exactly equal and opposite to the magnetic induction (F) due to the magnet. It can be shown by calculations that if d be the distance of the neutral point P from the centre of the magnet, and $2l$ be the length of the magnet, then the horizontal component B_H of the earth's magnetic induction for

1. North pole pointing north

$$B_H = \frac{\mu_0}{4\pi} \times \frac{M}{(d^2 + l^2)^{3/2}}$$

where M is the moment of the magnet ($M = 2\,ml$), and μ_0 is a constant called the *permeability of the medium*. For air or free space, $\mu_0 = 4\pi \times 10^{-7}$ henry/metre. If the magnet is short, the length l can be neglected as compared to the distance d,

i.e., $d >> l$.

Then,

$$B_H = \frac{\mu_0}{4\pi} \times \frac{M}{d^3} \quad \text{.......(1)}$$

2. South pole pointing north

$$B_H = \frac{\mu_0}{4\pi} \times \frac{2\,Md}{(d^2 - l^2)^2}$$

And for a short bar magnet

$$B_H = \frac{\mu_0}{4\pi} \times \frac{2\,M}{d^3} \quad \text{.......(2)}$$

In the above expressions, if we assume the value of B_H, the magnetic moment of the magnet can be calculated, i.e.,

$$M = \frac{4\pi\ B_H\ d^3}{\mu_0}\ \text{amp— m}^2\ \text{from} \quad \text{...(1)}$$

$$\text{and } M = \frac{4\pi\ B_H\ d^3}{2\,\mu_0}\ \text{amp — m}^2\ \text{from} \quad \text{...(2)}$$

Since $M = 2\,ml$ the pole strength of the magnet can also be calculated.

The unit for magnetic induction is the weber/ metre² or tesla.

Basic concepts

1. The space around a magnet in which its magnetic influence is felt is called a magnetic field.
2. According to Coulomb's Inverse square law

$$F = \frac{\mu_0}{4\pi} \times \frac{m_1 m_2}{r^2}$$

where m_1 and m_2 are the strength of two poles place r m apart in a medium of permeability μ_0 henry/m.

3. The unit of pole strength is ampere - m.
4. The unit of magnetic induction is the tesla.
5. Lines of magnetic induction do not intersect each other.
6. For the North pole pointing north , the null points are on the equatorial line of the bar magnet.
7. For the South pole pointing north, the null points are on the axial line of the bar magnet.

REVISION

I. Choose the correct answer.

1. For a bar magnet the magnetic induction is greatest
   a. at the poles. b. on the equatorial line. c. on the axial line. d. at the centre of the magnet.
2. The unit of magnetic induction is
   a. amp-m. b. amp/m². c. henry/m. d. tesla.

II. Fill in the blanks.

1. The space surrounding the magnet in which its magnetic influence is felt is the ________ .
2. The force between two magnetic poles is ________ proportional to the product of their pole strengths.
3. The force between two poles is ________ proportional to the ________ of the distance between them.
4. The unit of magnetic induction is ________ .
5. The unit of pole strength is ________ .
6. Lines of force start at a ________ pole and end at a ________ pole.
7. Lines of force do not ________ each other.
8. Parallel lines of induction indicate a ________ magnetic field.
9. The magnetic induction due to a short bar magnet with North pole pointing north is given by B_H = ________ .

10. The magnetic induction due to a short bar magnet with the South pole pointing north is given by B_H = ________.

III. State whether true or false.

1. For a bar magnet the magnetic induction is greatest at the poles.
2. The unit of permeability is amp-m.
3. Lines of magnetic induction start at a south pole.
4. The line joining the North and South poles of a magnet is the equatorial line.
5. For a magnet placed North pole pointing north, the null points are on the equatorial line.

IV. Answer the following questions.

1. State and explain Coulomb's Inverse Square Law.
2. How will you plot a magnetic field with a bar magnet for the North pole pointing north?
3. How will you plot a magnetic field with a bar magnet for the North pole pointing south?

V. Match the following :

1. Magnetic induction	a. line along the axis of a bar magnet.
2. Axial line	b. needle with one pole.
3. Compass needle	c. tracing lines of force.
	d. strength of the magnetic field.
	e. line perpendicular to the axis of the bar magnet.

8. Light – II

Total internal reflection - total reflecting prisms - optical instruments - photographic camera - simple and compound microscope - telescope - human eye and its defects with their correction - spectrum - infra red and ultra violet rays.

8.1 Total internal reflection

Consider what happens to light coming from a point *O* underneath water or glass. A ray *OP* normal to the surface goes straight through, and ray *OQ* is bent away from the normal.

As the angle *r* in the water increases, the angle *i* in the air increases until *i* is equal to 90°, i.e., the emergent ray grazes the surface of separation between the two media. If the angle of incidence in the medium is increased still further, no refraction takes place and the ray such as *OS* is reflected back into the medium. According to the laws of reflection such a ray is said to be *totally internally reflected* and the phenomenon is called *total internal reflection*. The angle *ORN* for which the emerging angle *MRS* is 90° is called the *critical angle C*. Hence, *the critical angle for a medium is the angle of incidence in the medium for which the angle of refraction in air is 90°*. Total internal reflection occurs when the angle of incidence exceeds the critical angle.

The refractive index (μ) of the medium is given by

$$\mu = \frac{\sin i}{\sin r}$$

$i = 90°; \quad r = C$

$$\text{Refractive index of water} = \frac{\text{sin of angle in air}}{\text{sin of angle in water}}$$

$$= \frac{\sin 90}{\sin C}$$

$$= \frac{1}{\sin C}$$

Thus the refractive index of water with respect to air is given by

$$\mu = \frac{1}{\sin C}$$

MIRAGE

A traveller in a desert sees a lake, with the sky and distant hills reflected in it. As he approaches

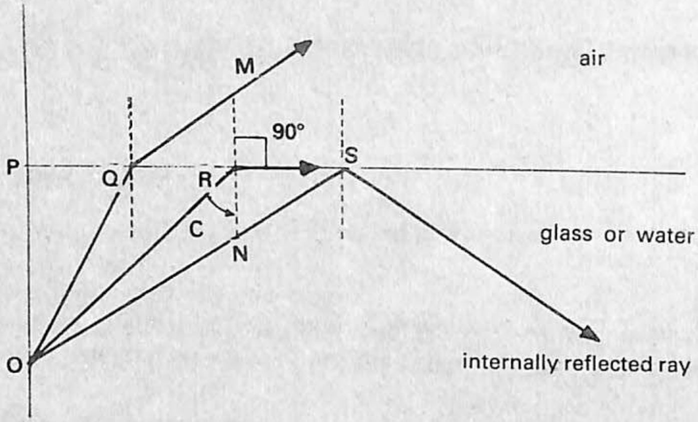


Fig. 8.1 Total internal reflection

it , the lake disappears or moves further off, and he finds only hot sand. What he actually saw earlier was a reflection at ground level, but the reflection was not by water, but by hot air. This phenomenon is called a *mirage*. You do not have to go to deserts to see mirages, they are often seen on roads on very hot days. Fig. 8.2 shows how this comes about.

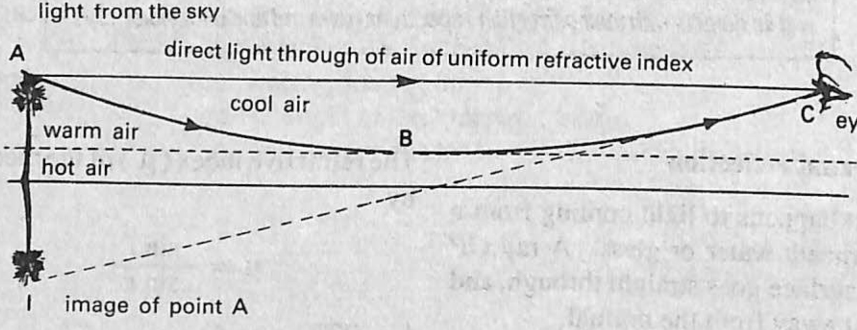


Fig. 8.2 Mirage : In a hot region

The sun's heat warms the sand or the road surface and this warms the air in contact with the sand. So the upper layers of air are cool and the lower layers are warm.

The density of warm air is less than that of cool air so that the light is bent away from the normal (denser upper layer to rarer lower layer). Finally, the angle of incidence on a warm layer is so large that it exceeds the critical angle and light is totally reflected, bends upwards and reaches the eye. An inverted image of the object is thus seen, by rays which are initially reflected at the lower layers of the atmosphere.

Another kind of mirage occurs in the arctic regions. Here images of ships are seen in the sky.

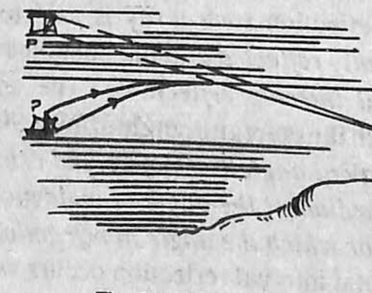


Fig. 8.3 Mirage : In a cold region

In the polar regions, the surface of the sea becomes very cold, resulting in the layers of air at the surface of the water becoming colder (and denser) than the layers above. Rays from any point of a ship starting upwards pass into a rarer medium and become more and more bent away from the normal until they suffer total internal reflection. Therefore, objects such as ships and icebergs appear to be projected up on the skies.

ATMOSPHERIC REFRACTION OF SUNLIGHT

A ray passing from vacuum to air is bent slightly towards the normal. Light from the sun, enters the atmosphere and travels towards the earth's surface. As it travels it passes through air of gradually increasing density and refractive index. Hence, the light is bent more and more towards the normal. The altitude of a heavenly body therefore appears greater than it really is and a correction for atmospheric refraction has to be applied in accurate astronomical work. It is for this reason that at sunset the sun is visible for about 7 $\frac{1}{2}$ minutes after it has set.

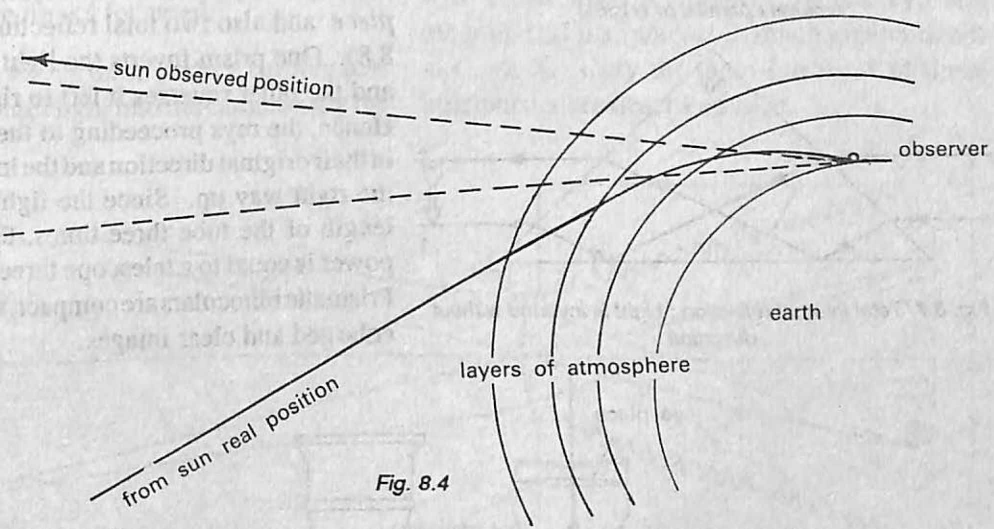


Fig. 8.4

8.2 Total reflection prisms

If the angle of a prism is 90° and the base angles are 45° each, the light entering at right angles to one of the shorter faces (refractive faces) makes an angle of incidence of 45° on the hypotenuse face. But the critical angle for glass is 42°. Since the angle of incidence is greater than the critical angle, the light is totally reflected according to the laws of reflection and is turned through 90°. Such prisms are used often instead of mirrors in periscopes (Fig. 8.5).

Total reflecting prisms can be used either to invert a beam of light, i.e., to reverse it left to right or to turn it upside down. Figs. 8.6 and 8.7 show how this is done. A pair of such prisms is used to reverse and then to give an erect image in a prismatic binoculars.

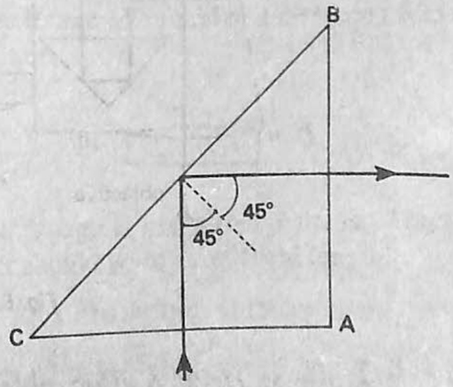


Fig. 8.5 Total internal reflection : Light turned through 90°

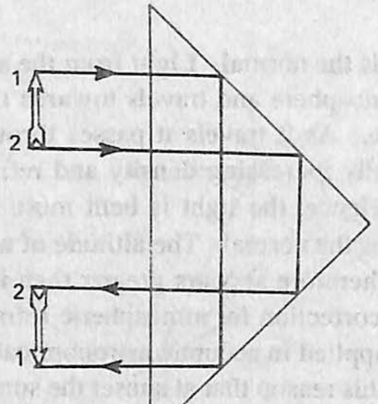


Fig. 8.6 Total internal reflection : Light is undeviated and emerges parallel to original

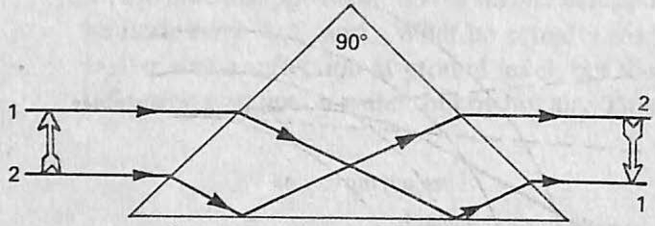


Fig. 8.7 Total internal reflection : Light is inverted without deviation

Total reflecting prisms have the following advantages over mirrors:

1. Reflection occurs at one surface only. There are no multiple images.
2. Nearly 100% of the light is reflected compared to 80% for a silvered glass mirror.
3. There is no need for silvering which will tarnish or wear off.

PRISMATIC BINOCULARS

This consists of two telescopes, one for each eye. Each telescope contains an *objective* and an *eye piece* and also two total reflecting prisms (Fig. 8.8). One prism inverts the light top to bottom and the other reverses it left to right (laterally). Hence, the rays proceeding to the eye piece are in their original direction and the image is formed the right way up. Since the light traverses the length of the tube three times, the magnifying power is equal to a telescope three times as long. Prismatic binoculars are compact, and give highly enlarged and clear images.

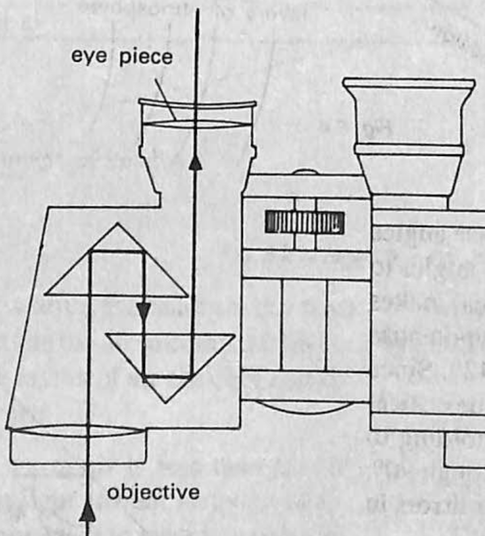


Fig. 8.8 Prismatic binoculars

Activity 1: ***Draw a diagram showing how total reflecting prisms may be used in a periscope.***

8.3 Optical instruments

1. THE PHOTOGRAPHIC CAMERA

Take any type of camera that is available and examine it. You will find it has three essential parts.

a. a light-tight box,
b. a convex lens, and
c. a light-sensitive plate or film.

The lens forms a real inverted image on the sensitive surface. The image is usually much smaller than the object focussed.

Apart from the above three parts, a camera has
a) a shutter to admit light into the camera only for a certain period of time. A normal snapshot exposure is about 1/20 of a second,
b) a hole or a stop of variable aperture. This as well as the shutter controls the amount of light entering the lens, and
c) bellows which can be made to fold up when the camera is not in use. This also allows the camera to be focussed by altering the distance of the lens from the film so that all objects can be sharply focussed on to the film.

Fig. 8.9 shows the action of a camera. You will again study the camera, human eye and other optical instruments in much greater detail in Class X. Only the main functions of these instruments are described here.

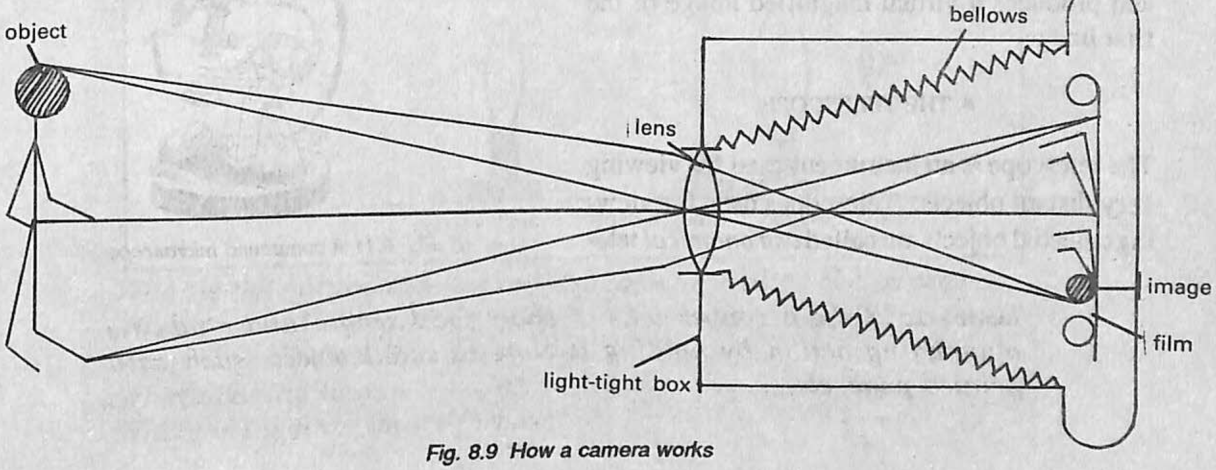


Fig. 8.9 How a camera works

2. SIMPLE MICROSCOPE OR MAGNIFYING GLASS

You learnt in Chapter 5 that when an object is placed near a convex lens at a distance less than its focal length, a magnified erect image is formed. When used like this, the lens is called a magnifying glass or a simple microscope. The image would be most clearly seen if it were formed at the least distance of distinct vision, i.e., 25 cm from the eye. Now, the magnification in a lens is given by

$$m = \frac{\text{size of image}}{\text{size of object}}$$

$$m = \frac{v}{u}$$

Hence, if the lens is placed 5 cm from an object and the image is formed at a distance of 25 cm then

$$m = \frac{25}{5} = 5$$

i.e., the image is magnified 5 times. The lens chosen should be of short focal length.

3. COMPOUND MICROSCOPE

For very small objects the magnification produced by a simple microscope is not enough. To produce greater magnification, two convex lenses are used. The first, the objective, produces a real

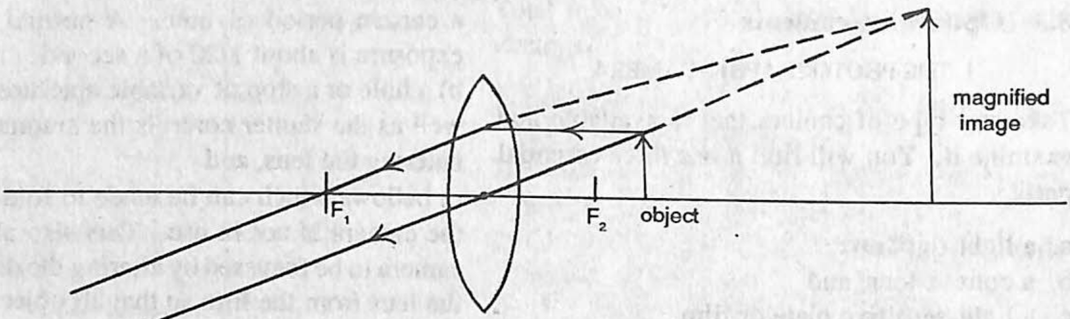


Fig. 8.10 How a simple microscope works

magnified image of the object. This image becomes the object for the second lens, the eye piece, which acts as a simple magnifying glass and produces a virtual magnified image of the first image.

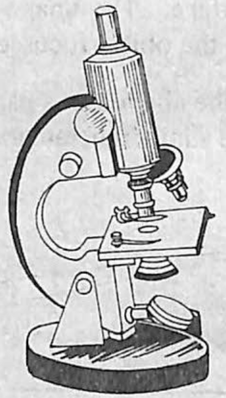


Fig. 8.11 A compound microscope

4. THE TELESCOPE

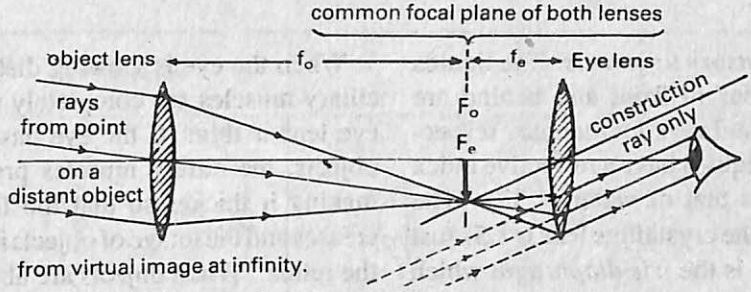
The telescope is an instrument used for viewing very distant objects. Telescopes used for viewing celestial objects are called *astronomical* telescopes, while those used for viewing terrestrial objects are called *terrestrial* telescopes.

Activity 2: *Take a convex lens of short focal length and study its magnifying action by holding it close to small objects such as a printed page, etc.*

Activity 3: *Mount two convex lenses on separate stands and form a compound microscope. Place the lens of shorter focal length as the objective. Is the image real or virtual? .... magnified or diminished? .... inverted or erect?*

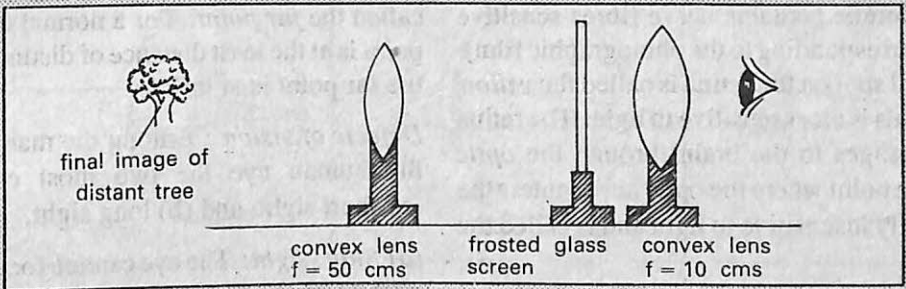
The astronomical telescope : In its simplest form it consists of 1) an objective of large focal length. It forms an inverted, diminished image of the distant object in its focal plane, and 2) an eyepiece of short focal length which acts as a magnifying glass to form the final image, either at infinity or at the least distance of distinct vision.

The terrestrial telescope : The final image formed by an astronomical telescope is inverted. This does not matter if we are looking at a star or a planet or the moon, but if we want to view a distant ship, or to detect the enemy, then it would be more convenient to view them the right way up. This can be achieved by using a third convex lens of short focal length between the objective and the eye piece. This lens is called the *erecting lens.*


common focal plane of both lenses
object lens
f_o
f_e
Eye lens
rays from point on a distant object
F_o
F_e
construction ray only
from virtual image at infinity.

Activity 4: *Construct a simple telescope.*

Mount a convex lens with a focal length of 50 cm and turn it towards a distant object such as a tree. Adjust a frosted glass screen on the other side so that a clear image is formed on it. Place a convex lens with a focal length 10 cm as an eyepiece behind the screen and view the image through this.



What is the nature and size of the image formed on the screen?
When viewed through the eyepiece is there any change in this image?
What does the first lens do?
What does the second lens do?
Where is the final image formed?

5. THE HUMAN EYE

The optical principle of the working of the human eye is identical to that of the camera. As you already know, a camera has three essential parts i.e, a light-tight box, a convex lens, and a light-sensitive plate or film.

In the human eye, the light-tight box is found in the eyeball which is nearly spherical in shape and slightly bulging in front. The eyeball has a tough outer coating called the *sclerotic*.

The transparent bulging portion in front is called the *cornea*, through which light enters the eye. Behind the cornea the *crystalline lens* is supported by *ciliary muscles* which are attached

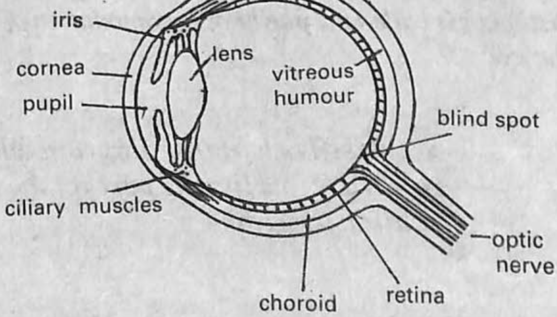


Fig. 8.12 The human eye

to the lens by *suspensory ligaments.* The liquids which cover the lens in front and behind are known as *aqueous* and *vitreous humour,* respectively. Both these liquids have a refractive index almost the same as that of water (1.33). The refractive index of the crystalline lens is 1.5. Just in front of the lens is the *iris diaphragm* which corresponds to the 'stop' in a camera. The hole in the iris, through which light enters the eye, is called the *pupil.* This is the round black central part surrounded by the coloured iris. The inner surface of the sclerotic is lined by the *choroid* which contains a black pigment that absorbs unwanted light. Over the choroid is a membrane lining the inner wall of the eyeball — the *retina.* This membrane contains nerve fibres sensitive to light (corresponding to the photographic film). The central spot on the retina is called the *yellow spot* and this is most sensitive to light. The retina sends messages to the brain through the *optic nerve.* The point where the optic nerve enters the eye is totally insensitive to light and is called the *blind spot.*

Action of the eye: The distance between the crystalline lens and the retina is fixed. Even so, the eye is able to clearly see objects which are at various distances from the eye. This is because the focal length of the eye - lens is altered by the action of the ciliary muscles, so that the image is always is formed on the retina. This action is called *accomodation. The power of the eye to adjust itself so as to see objects at different distances is called the power of accomodation of the eye.*

When the eye is viewing distant objects, the ciliary muscles are completely relaxed and the eye lens is thin. If the eye has to view nearer objects, the ciliary muscles press on the lens making it thicker so that the focal length decreases and the image of objects is still formed on the retina. When objects are about 25 cm from the eye the ciliary muscles have expanded to the maximum and cannot change the focal length of the eye any further. This shortest distance within which the eye cannot distinctly see objects, is called the *least distance of distinct vision.* The point upto which the eye cannot see objects distinctly is called the *near point.* The farthest point upto which the eye can see objects clearly is called the *far point.* For a normal eye, the near point is at the least distance of distinct vision and the far point is at infinity.

Defects of vision : Among the many defects of the human eye the two most common are (a) short sight, and (b) long sight.

(a) Short sight: The eye cannot focus on distant objects as the rays focus in front of retina. A concave lens is used to correct this. It diverges the light entering the eye so that the image is formed on the retina.

(b) Long sight: The eye cannot focus on a close object because the rays from it are focussed behind the retina. This may be corrected by causing the rays to converge through a convex lens before entering the eye.

The fig. 8.13 shows the defects of vision and their correction.

Activity 5: *Look at the diagram which compares the human eye to the camera. Now list the parts of the human eye and camera which have similar functions.*

Activity 6: *Draw the same diagram on a sheet of chart paper to a much larger scale.*

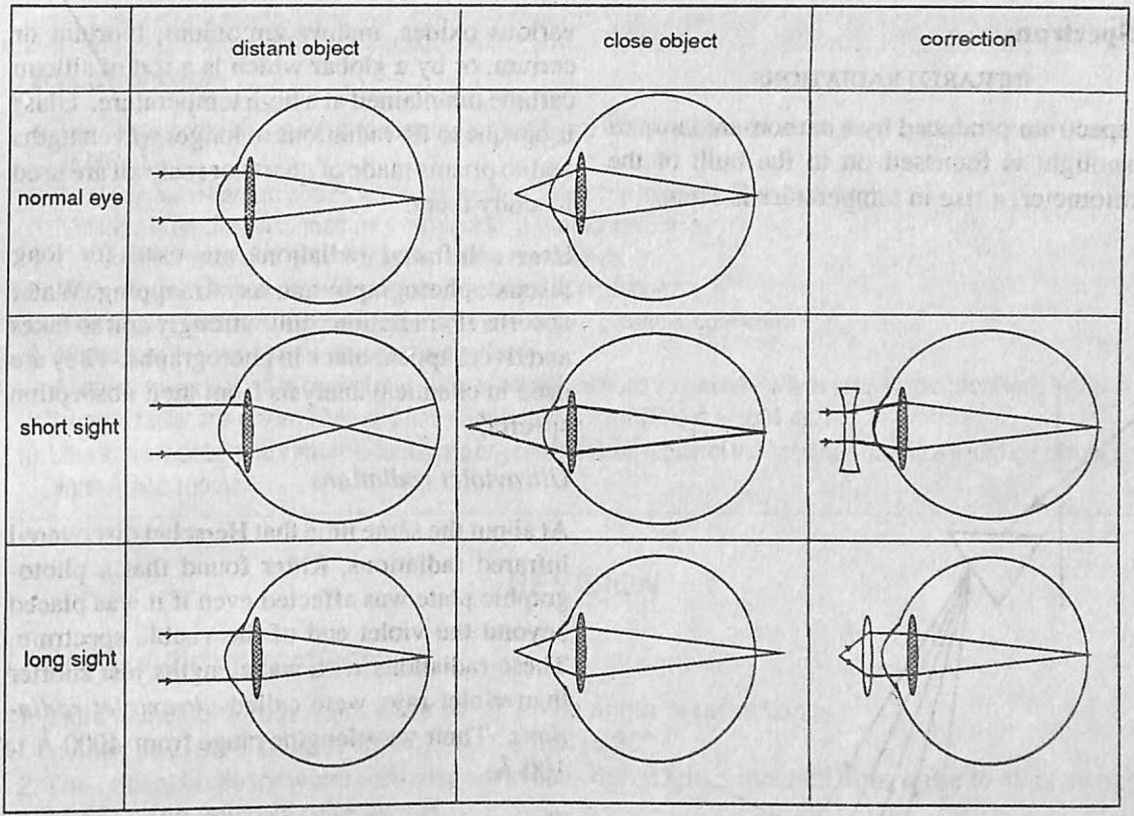


Fig. 8.13 Defects of the eye and their correction

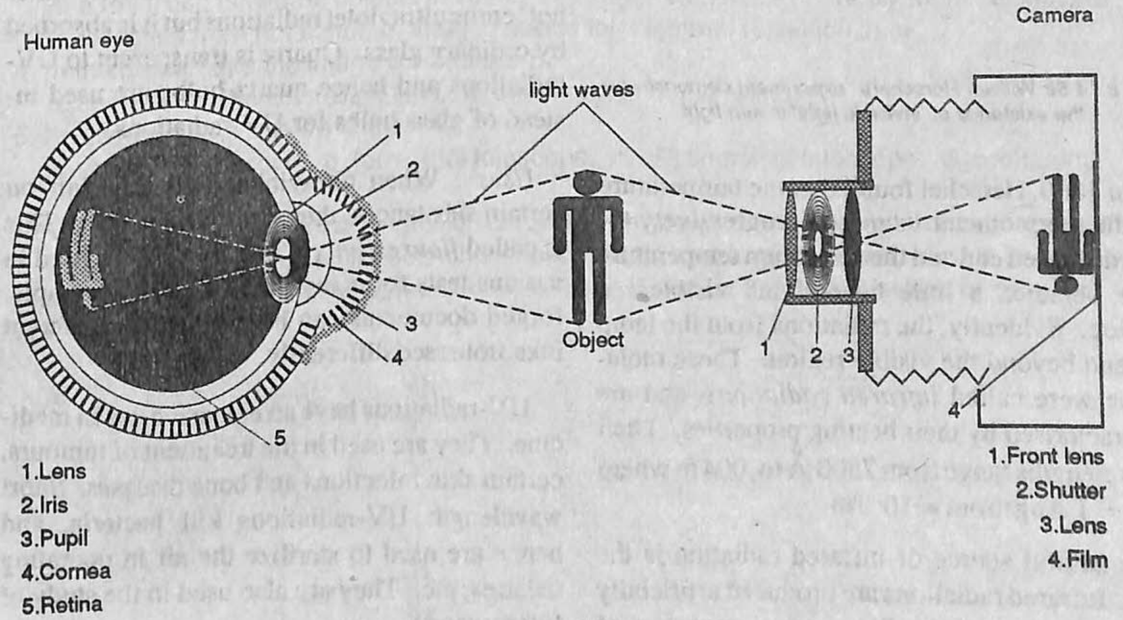


Fig. 8.14 Comparison of the eye and camera

8.4 Spectrum

INFRARED RADIATIONS

If a spectrum produced by a carbon-arc lamp or by sunlight is focussed on to the bulb of the thermometer, a rise in temperature is seen.

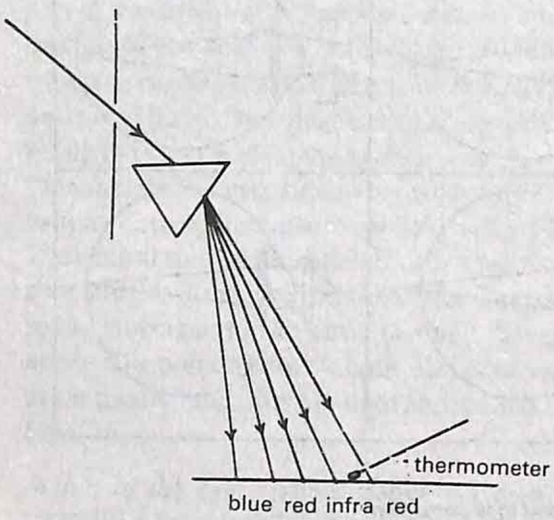


Fig. 8.14 Sir William Herschel's experiment demonstrates the existence of 'invisible light' in sun light.

In 1800, Herschel found that the temperature of the thermometer increased progressively towards the red end and the maximum temperature was obtained a little beyond the visible red region. Evidently, the radiations from the lamp extend beyond the visible region. These radiations were called *infrared radiations* and are characterised by their heating properties. Their wavelengths range from 7500 Å to .004 m where 1 Å = 1 Angstrom = 10^{-10}m.

The natural source of infrared radiation is the sun. Infrared radiations are produced artificially by glowers which are filaments of a mixture of various oxides, mainly zirconium, thorium or cerium, or by a globar which is a rod of silicon carbide maintained at a high temperature. Glass is opaque to IR-radiations of longer wavelengths and so prisms made of quartz or rocksalt are used to study them.

Uses : Infrared radiations are used for long distance photography and aerial mapping. Water absorbs IR-radiations quite strongly and so lakes and rivers appear black in photographs. They are used in chemical analysis from their absorption spectra.

Ultraviolet radiations

At about the same time that Herschel discovered infrared radiations, Ritter found that a photographic plate was affected even if it was placed beyond the violet end of the visible spectrum. These radiations with wavelengths just shorter than violet rays were called *ultraviolet radiations*. Their wavelengths range from 4000 Å to 100 Å.

The sun is a source of ultraviolet radiations, but most of the radiations are absorbed by the earth's atmosphere. Any object that is heated 'white hot' emits ultraviolet radiations but it is absorbed by ordinary glass. Quartz is transparent to UV-radiations and hence quartz bulbs are used instead of glass bulbs for UV-radiations.

Uses : When ultraviolet radiations fall on certain substances, they emit visible light. This is called *flourescence*. This property is used in various tests for many purposes. For example, forged documents can be detected as different inks flouresce differently.

UV-radiations have an extensive use in medicine. They are used in the treatment of tumours, certain skin infections and bone diseases. Short wavelength UV-radiations kill bacteria, and hence are used to sterilize the air in operating theatres, etc. They are also used in the study of fluorescence.

Basic concepts

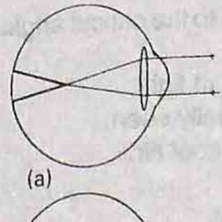
1. The critical angle of a medium is the angle of incidence in the medium for which the angle of refraction in air is 90°.
2. Total internal reflection occurs when the angle of incidence exceeds the critical angle.
3. A mirage is an illusion formed as a result of total internal reflection.
4. The action of a camera is similar to that of the human eye.
5. A convex lens of short focal length forms a simple microscope.
6. A compound microscope consists of two lenses to give greater magnification.
7. A telescope is used to view distant objects clearly.
8. A concave lens is used to correct myopia or short sightedness and a convex lens is used to correct long sight.
9. Infrared radiations are invisible and have wavelengths from 7500 Å to .004 m.
10. Ultra violet radiations are invisible radiations beyond the violet region of the spectrum having wavelengths from 4000 Å and 100 Å.

REVISION

I. Choose the correct answer.

1. Light is incident from water to air at 30°. The angle of refraction is
   a. less than 30°. b. more than 30°. c. equal to 30°.
2. The critical angle for water with respect to air is 48°. Light is incident from water to air at an angle of 48°. The angle of refraction is
   a. less than 48°. b. equal to 48°. c. equal to 90°. d. more than 48° and less than 90°.
3. A person seeing a mirage, really sees
   a. a reflection of distant objects in water. b. images which are not really there. c. images due to reflection from hot sand. d. images due to total internal reflection in air.
4. In the human eye the image is formed on
   a. camera. b. the crystalline lens. c. the choroid. d. the retina.
5. An erecting lens is used in the
   a. simple microscope. b. terrestrial telescope. c. astronomical telescope. d. compound microscope.
6. Two lenses A and B of focal lengths 50 cm and 10 cm are available to construct a telescope, then,
   a. lens A should be used as objective and lens B as eyepiece. b. lens B should be used as objective and lens A as eyepiece. c. either A or B can be used as objective or eyepiece.
7. The myopic eye is

   a.



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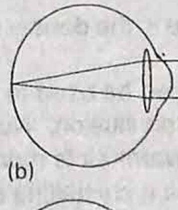

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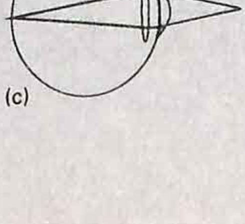

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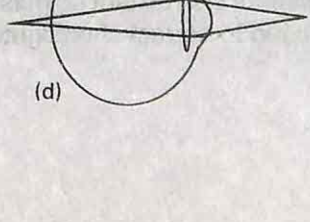


(d)

II. Fill in the blanks.

1. Total internal reflection occurs when light travels from a ________ medium to a ________ medium.
2. Total internal reflection occurs when the angle of incidence is greater than the ________ .
3. When light is incident in the denser medium at the critical angle, the angle of refraction in the rarer medium is ________ .
4. The refractive index of a medium expressed in terms of the critical angle is ________ .
5. A mirage is due to ________ ________ ________ of light travelling from colder layers of air to warmer layers.
6. Mirages occur mostly in ________ regions and ________ regions.
7. The critical angle for glass with respect to air is ________ degrees.
8. Total reflection prisms are used in ________ ________ .
9. In a camera, the image is formed by a ________ lens.
10. If the critical angle is C, then $\mu =$ ________ .
11. The refractive index of the crystalline lens in the eye is ________ .
12. The membrane in the eye containing nerve fibres sensitive to light is called ________ .
13. The point in the eye which is totally insensitive to light is called the ________ .
14. ________ is the ability of the eye to see near and far objects.
15. The shortest distance within which the eye cannot distinctly see objects is called ________ .
16. The point upto which the eye cannot see distant objects clearly is called ________ .
17. The farthest point upto which the eye can see objects clearly is called the ________ .
18. In a nearsighted eye the image of a distant object is formed ________ the retina.
19. In a longsighted eye the image of a distant object is formed ________ the retina.
20. The power of a lens is measured in ________ .
21. For a simple microscope the object should be placed at a distance ________ than the focal length of the lens.
22. For a compound microscope both the lenses must be of ________ focal length.
23. In a telescope, the objective is of ________ focal length and the eyepiece is of ________ focal length.
24. In a terrestrial telescope, a third convex lens called the ________ is used.

III State whether the following are true or false:

1. For total internal reflection to take place,light should be incident at the critical angle in the denser medium.
2. For an angle of incidence in the denser medium equal to the critical angle, the angle of refraction is 90°.
3. A total reflection prism can be used to invert a beam of light.
4. A mirage is nothing but an illusion. No image is actually seen.
5. The refractive index of warm air is more than that of cool air.
6. The human eye contains a crystalline concave lens.
7. The central point on the retina is called the blind spot.
8. The myopic eye cannot see distant objects clearly.
9. A convex lens is used to correct shortsightedness.

10. For a normal eye the near point is at the least distance of distinct vision.
11. In a simple microscope, the real image of the object is formed.
12. The final image of an object formed in a compound microscope is inverted.
13. In a telescope the objective should be of shorter focal length.
14. The wavelength of ultraviolet radiation is greater than that of visible light.
15. Infrared radiations are heat radiations.

IV. Problems.

1. The critical angle for glass is 42°. Find the refractive index of glass. (Ans. 1.49)
2. The refractive index of water is 4/5. Find its critical angle. (Ans. 48.6°)
3. Light is incident on a glass slab at 52°. If the angle of refraction is 30°, what is the refractive index of glass? (Ans. 1.576)

V. Answer the following questions :

1. Draw a neat diagram and explain the terms 'critical angle' and 'total internal reflection'. What are the conditions necessary for total internal reflection to occur?
2. Explain the formation of mirage.
3. Show by a ray diagram how a right-angled glass prism may be used
   a) to turn a ray through 90°.
   b) to turn a ray through 180°.
   c) to invert a beam of light.
4. Describe with a neat diagram the prism binoculars.
5. Explain with neat diagrams the defects of vision. How can they be remedied ?
6. Describe with a neat diagram the action of a simple microscope.
7. Compare the properties and uses of infrared and ultraviolet radiations.
8. Draw a neat diagram of a camera and explain how it works.

VI. Match the following:

1. far appears near	a. long sight
2. myopia	b. telescope
3. small appears big	c. total internal reflection
4. shutter	d. short wavelength
5. mirage	e. microscope
6. ultraviolet rays	f. shortsight
	g. retina
	h. heat radiation

9. Magnetism — II

Earth's magnetism - dip and inclination - declination - horizontal component

EARTH AS A MAGNET

The earth behaves like a huge magnet with its magnetic poles near the geographic north and south poles. As a result, when a small magnet is suspended by an unspun thread from its centre of gravity, it will not be horizontal but comes to rest in the direction of the earth's magnetic field in an inclined position. If this suspended magnet is taken to the northern hemisphere, the north pole *N* of the suspended magnet will dip more and more towards the earth and will be vertical at the magnetic North pole of the earth. Similarly, if the same magnet is taken to the southern hemisphere, the south pole *S* of the needle will dip as shown in Fig. 9.1 where *N-S* represents the imaginary magnet held at the centre of the earth.

The lines of magnetic induction due to the earth's magnetism may be shown diagramatically as in the figure.

The *magnetic meridian* at any place is a vertical plane passing through the place and containing the magnetic axis of a freely suspended magnet.

The *geographic meridian* at any place is the plane passing through the place and the earth's axis of rotation.

The angle between the geographic meridian and the magnetic meridian at a place is called the magnetic *declination* at that place.

When a magnet is free to rotate in the magnetic meridian it comes to rest in an inclined direction along the direction of the earth's magnetic induction at a place. The angle between the direction of the earth's magnetic induction and the horizontal is called the angle of *dip* or *inclination*.

If we plot the magnetic lines of induction on a paper when no magnets are in the vicinity, a number of parallel straight lines are obtained. This represents the earth's magnetic field in a horizontal plane and is called the *horizontal component* of the earth's magnetic induction B_H field.

The angles of declination and dip and the horizontal component of the earth's magnetic induc-

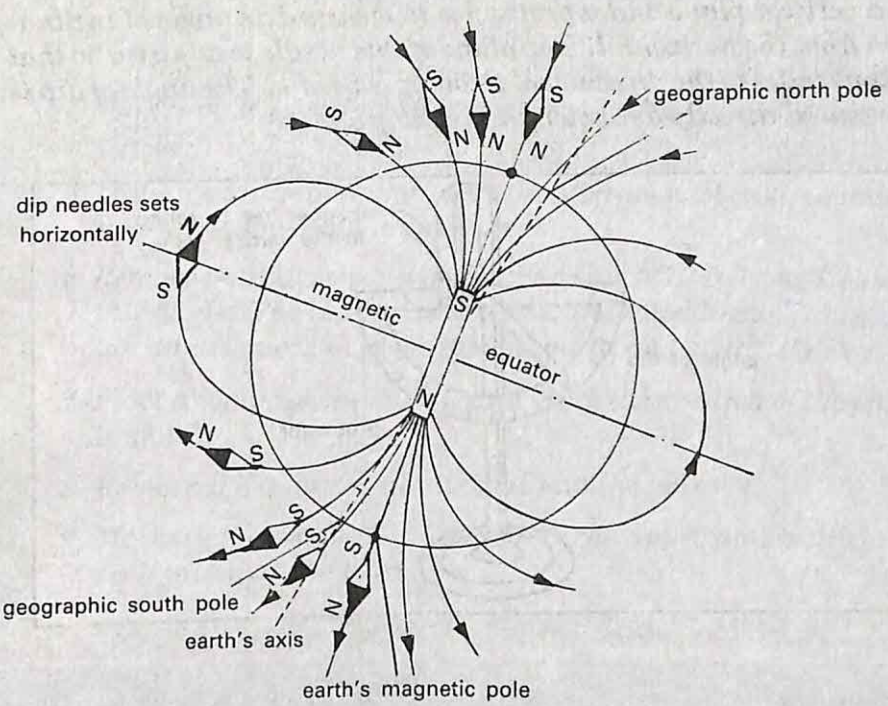


Fig. 9.1 The earth as a magnet

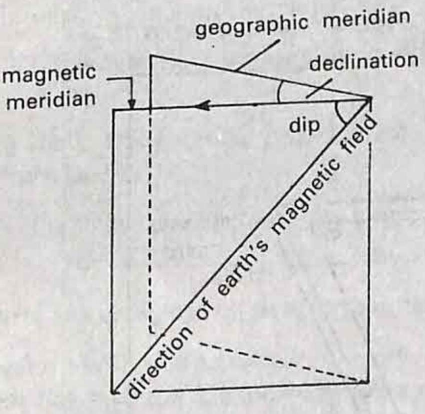


Fig. 9.2 Declination

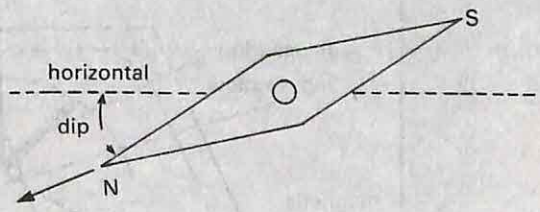


Fig. 9.3 Dip

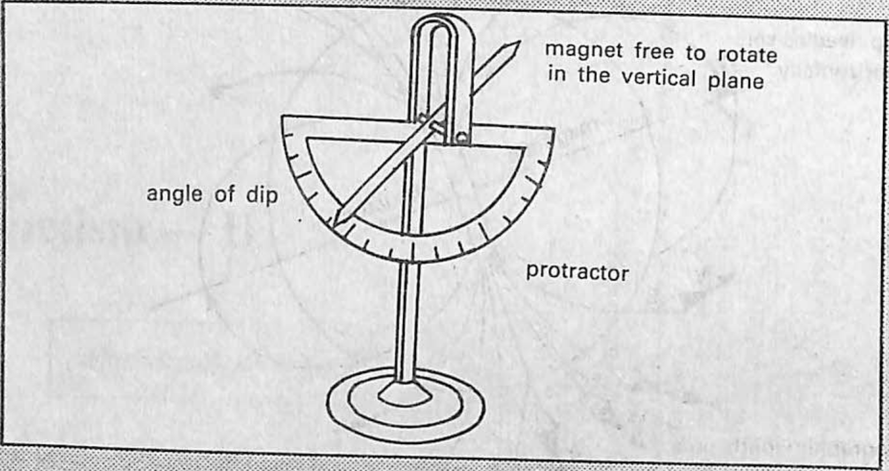
tion are known as the *magnetic elements* of a place.

The three magnetic elements at a place are diagramatically shown in the Fig. 9.2 .

MEASUREMENT OF DIP

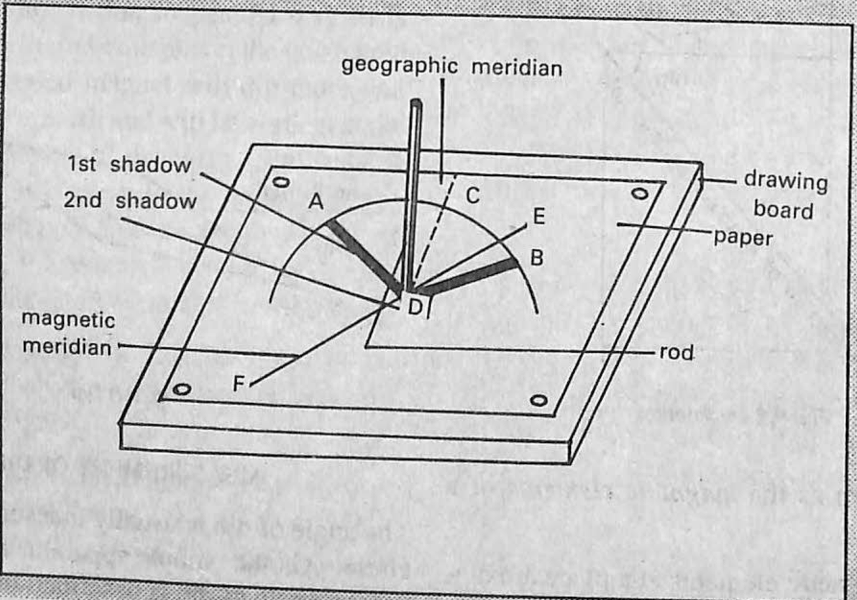
The angle of dip is usually measured with a dip circle. Another simple apparatus used to measure the angle of dip is described in Activity 1.

Activity 1: *The apparatus consists of a magnetized needle free to turn in a vertical plane and a protractor to measure its angle of inclination from the horizontal. The plane of this needle is adjusted so that it is parallel to the direction of a compass needle. The angle of dip is measured directly as shown in the diagram.*



Activity 2: Measurement of declination

1. *Pin a sheet of paper on to a drawing board.*
2. *Fix a vertical rod on the paper at O, as shown in the diagram.*



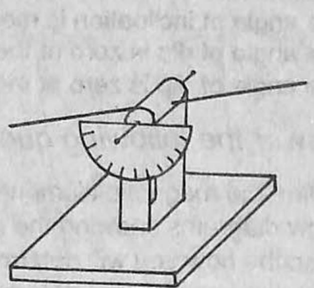
3. *With O as the centre and any radius draw a semicircle about O.*
4. *An hour or so before noon keep watching the shadow and when its length just touches the semicircle mark its position A on the circle.*
5. *Make a similar observation in the afternoon when the shadow again just touches the circle at B.*
6. *Remove the rod, you will notice the angle AOB is formed. Bisect this angle. The bisector is shown with dotted lines. This gives the direction of the geographical north and south (OC).*
7. *Place a compass needle at O and mark the position of the poles E and F.*
8. *Remove the compass needle and join the points EF.*
9. *Measure the angle EOC, this gives the approximate angle of declination at the place.*

Basic concepts

1. The earth behaves like a huge magnet with its magnetic north in the southern hemisphere and the magnetic south in the northern hemisphere.
2. The angle of declination at a place is the angle between the geographic meridian and the magnetic meridian at a place.
3. The angle of dip at a particular place is the angle between the direction of the earth's magnetic induction and the horizontal.
4. The horizontal component of the earth's magnetic induction is the third magnetic element at a place.

Some investigatory projects/activities

Push a steel knitting needle through a cork in a direction parallel to a diameter of its ends. Balance it horizontally on a U-piece of brass strip using pins as an axle (see diagram). Take it off the knife edges and magnetize without disturbing the cork. When it is replaced on the bearings, one end will be pulled downwards by the earth's magnetic field. The protractor serves to measure this angle of 'dip.'

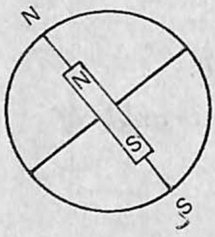


An alternative way of suspending the magnet is to use a piece of cycle valve tubing with a pin pushed through it as a supporting axle. Knife edges can be provided by two postcards held apart by corks maintained in position by drawing pins. The position of dip can then be marked with a pencil and measured later.

REVISION

I. Choose the correct answer.

1. The angle between the direction of the earth's magnetic induction is called
   a. declination. b. magnetic meridian. c. dip. d. geographic meridian.
2. The earth as a magnet can be shown as



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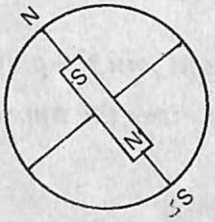

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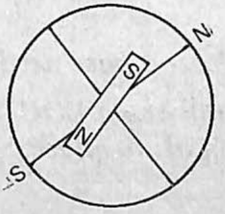

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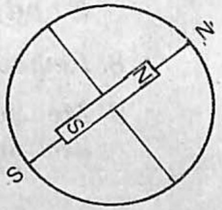


(d)

II. Fill in the blanks.

1. The dip, declination and horizontal induction are the ________ ________ at a place.
2. The angle between the geographic and magnetic meridians is called ________ ________.
3. The south pole of the earth's imaginary magnet is in the ________ hemisphere.
4. The ________ pole of the magnetic needle dips in the southern hemisphere.
5. The plane passing through a place and the earth's axis of rotation is called ________ at that place.

III. State whether true or false.

1. The magnetic meridian, declination and dip are the magnetic elements at a place.
2. The angle between the geographic meridian and magnetic meridian is called the angle of inclination.
3. The angle of inclination is measured with a dip circle.
4. The angle of dip is zero at the equator.
5. The angle of dip is zero at the poles.

IV. Answer the following questions:

1. Define the magnetic elements at a place.
2. Draw diagrams showing the three magnetic elements at a plaqce.
3. Describe how you will determine the angle of dip in the laboratory.
4. Describe how you will determine the angle of declination in the laboratory.

10. Electricity

Electrictiy at rest - production - theory of electrification - electroscope - charge density - electricity in motion - voltaic cell - dry cell and storage battery - Ohm's law - resistance - household circuiting - atomic physics - production of a stream of electrons by heat and light - diode valve.

10.1 Electricity at rest

1. PRODUCTION

Everyone is familiar with the fact that if a pen or a comb made of certain plastic materials is rubbed on a coatsleeve, it attracts small pieces of paper. The same effect is noticed when a mirror or windowpane is polished with a dry cloth in a very dry atmosphere. Dust and fluff from the cloth stick to the glass and are difficult to remove. The phenomenon is called electric attraction and the rubbed materials are said to have become charged with *static electricity*. This knowledge goes back as far as the sixth century B.C. when the Greek philosopher, Thales, described the attractive properties of rubbed amber. The word 'electricity' has, in fact, been derived from the Greek work '*elektron*' meaning amber.

Two kinds of electricity are developed when bodies are rubbed together, i.e., *positive electricity* and *negative electricity*. Electricity devel-

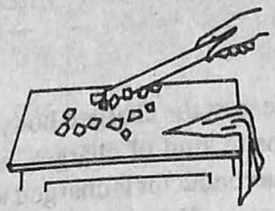


Fig. 10.1 Charging with static electricity

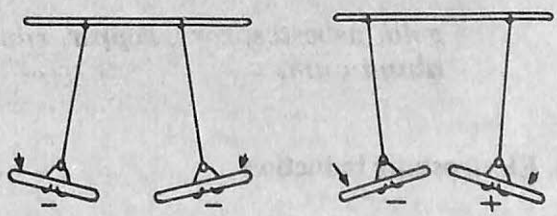


Fig. 10.2 Similar charges repel each other; unlike charges attract each other.

oped on glass rubbed with silk is positive electricity and electricity developed on ebonite rubbed with fur is negative electricity. The positive and negative electricity are generally known as positive and negative charges. Similar charges repel each other. Opposite charges attract each other.

Activity 1: *Recall:*

1. *What does the atom consist of?*
2. *Which particles are found in the nucleus?*
3. *What is the charge on the nucleus?*
4. *What charge does the atom have?*
5. *Which particles are outside the nucleus?*
6. *What can you say about the number of protons and electrons in an atom?*

2. THEORY OF ELECTRIFICATION - THE ELECTRON THEORY

You have already learnt about the structure of the atom in Class 8.

How does a body get electrified by friction?

Tremendous forces are required to separate a proton from the nucleus of an atom. However, it is quite easy to cause an electron to leave an atom or to move to another atom. When an ebonite rod is rubbed with fur, electrons are transferred from the fur to the ebonite and the rod becomes negatively charged. The fur, having lost electrons becomes positively charged. Similarly, when a glass rod is rubbed with silk, electrons are transferred from the glass to the silk so that the glass becomes positive because it loses electrons and the silk becomes negative because it gains electrons. Hence, a body which loses electrons is positively charged and a body which gains electrons is negatively charged.

3. CONDUCTORS AND INSULATORS

In some materials (mainly metals) the orbital electrons are so loosely bound that they will leave the atom readily. In other substances the electrons are so tightly bound to their nuclei that they hardly move out of their atom.

Materials in which the electrons can move readily are called *conductors*. Substances in which the electrons cannot move readily are called *insulators*.

Activity 2: *From the list of materials given below classify the conductors and insulators.*

gold, asbestos, cork, copper, silver, wood, paper, iron, rubber, mica, aluminium.

4. Electrostatic induction

If a charged body is placed near an uncharged conductor, a separation of charges takes place in the conductor. The end of the insulated conductor which is nearest the charged body is charged with the opposite kind of charges, and the farthest end of the conductor is charged with similar kind of charges. This is called *electrostatic induction.*

To charge a body positively by induction

If a body *B* is to be charged positively, take a negatively charged body *A* (an ebonite rod rubbed with fur) and bring it close to one end of body *B*. Separation of charges takes place in *B*. The end close to *A* gets the opposite charge (positive) and the end away from *A* gets a similar charge (negative). Now connect the further end of *B* to the earth. This may be done by just touching the end with the finger. The negative charges flow to the earth. Remove the body *A* and the earth connection (your finger) simultaneously. The positive charge spreads over the whole body. Thus the insulated conductor *B* has been charged positively.

To charge a body negatively by induction

If the uncharged insulated conductor *B* is to be charged negatively by induction, a positively charged body *A* (a glass rod rubbed with silk) is placed near the body *B*. The end closer to *A* gets charged (negatively) by induction and the end away from *A* gets positively charged. Connect the further end of *B* to the earth. Negative charges flow from the earth to the body and neutralise the positive charges. The negative charges are 'bound' as long as *A* is present and cannot flow to the earth. Remove the body *A* and the earth connection at the same time. The negative charge spreads over the whole body *B*. Thus *B* is charged negatively by induction.

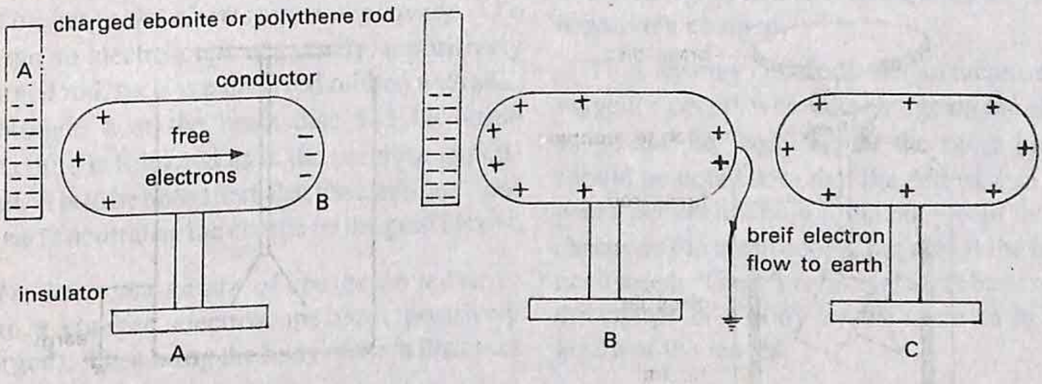


Fig. 10.3a. Charging a body positively by induction

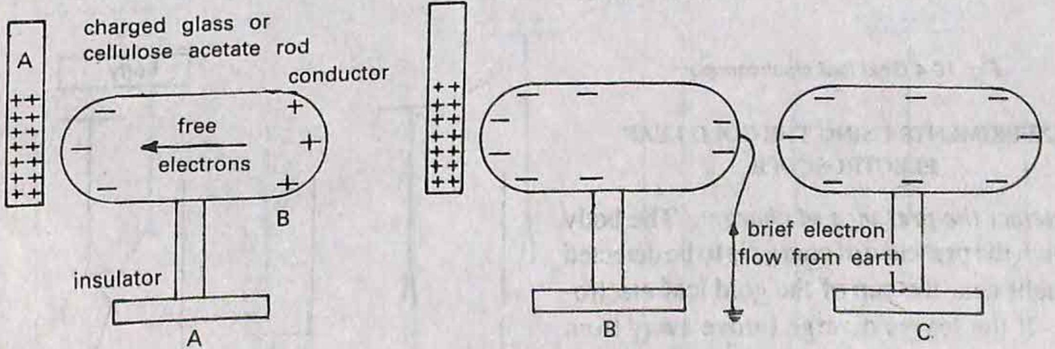


Fig. 10.3b. Charging a body negatively by induction

GOLD LEAF ELECTROSCOPE

The gold leaf electroscope is a very sensitive instrument for detecting the charge on a body. It consists of a brass disc fixed to a brass rod. The lower end of the brass rod has two thin foils of gold known as gold leaves. The brass rod passes through an ebonite stopper fitted to the neck of a glass jar as shown in Fig. 10.4. On the inner wall of the glass jar and facing the leaves are two strips of tin foil. The base of the instrument is also covered with tin foil. The tin foils are connected to the earth. The earth is kept dry by some fused calcium chloride kept in a dish.

A schematic diagram of the gold leaf electroscope is shown in Fig.10. 5 .

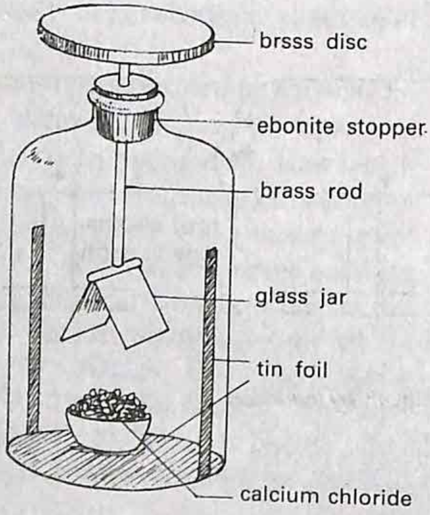


Fig. 10.4 Gold leaf electroscope

EXPERIMENTS USING THE GOLD LEAF ELECTROSCOPE

1. To detect the presence of charge : The body for which the presence of charge is to be detected is brought near the cap of the gold leaf electroscope. If the leaves diverge (move away from each other), then the body is charged. Very small charges can be detected with the gold leaf electroscope.

2. To charge a gold leaf electroscope positively: This is usually done by induction. Hold a rod which is negatively charged, such as an ebonite rod rubbed with flannel, close to the brass disc.

The brass disc which is closer to the rod acquires an opposite (positive) charge while the gold leaves which are at the other end acquire the same (negative) charge. With the charged rod still held in place, the disc is connected to the earth. The negative charge on the leaves flow to the earth. Since there is no charge on the gold leaves they now collapse. The charge on the disc remains bound due to the presence of the charged rod. The leaves diverge again. Now remove the earth connection and then the rod. The positive

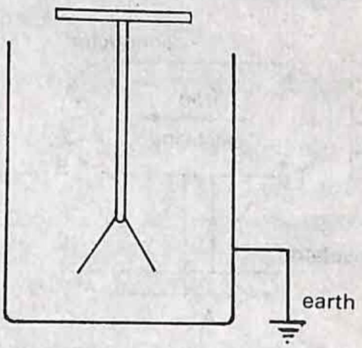


Fig. 10.5 Schematic diagram of gold leaf electroscope

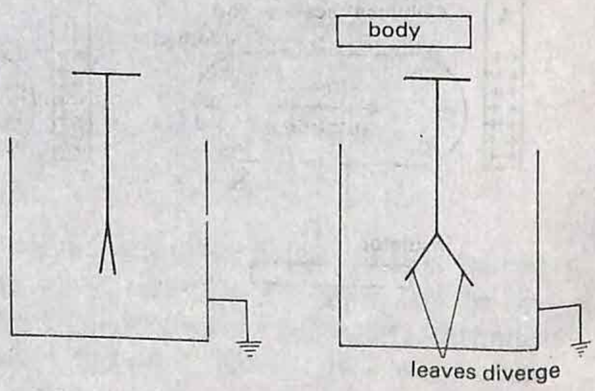


Fig. 10.6 Detecting the presence of a charge

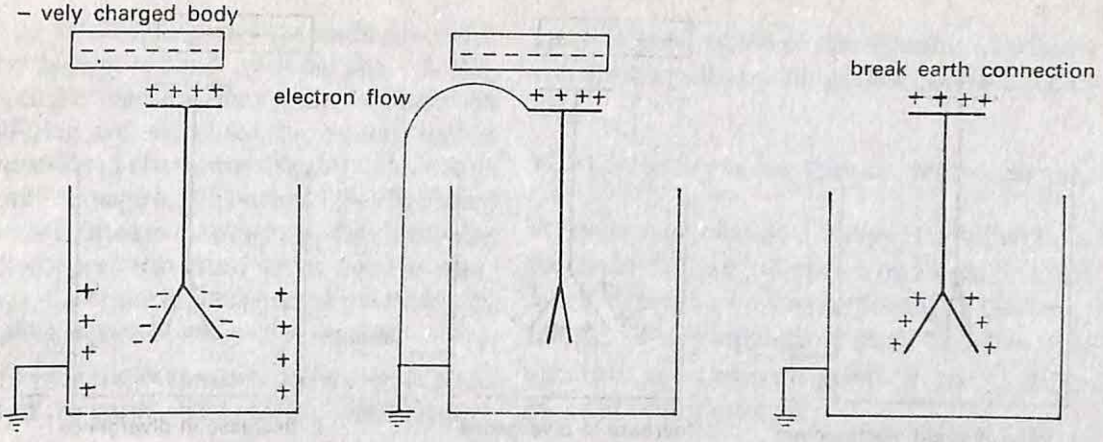


Fig. 10.7 Charging a gold leaf electroscope positively

charges on the disc spread over the whole of the brass disc and gold leaves. Thus the electroscope is charged positively.

3. To charge the electroscope negatively: To charge an electroscope negatively, a positively charged rod, such as a glass rod rubbed with silk, is brought near the brass disc and the same procedure is followed as in the previous experiment. It is to be noted here that the electrons from the earth neutralise the charge on the gold leaves.

4. To detect the nature of charge on a body : Take a charged electroscope (say, positively charged). Then bring the body close to the brass disc of the electroscope. Since we have taken a positively charged electroscope, if the divergence of the leaves increases, the body is positively charged, and if it decreases, the body is negatively charged.

Thus we may conclude that an increase in divergence occurs when the charge on the electroscope and the body are of the same kind. It should be noted here that the decrease in divergence occurs not only if the body is of the same charge as the electrocope, but also if the body is uncharged. Therefore, it is always better to test the charge of a body by the increase in divergence of the leaves.

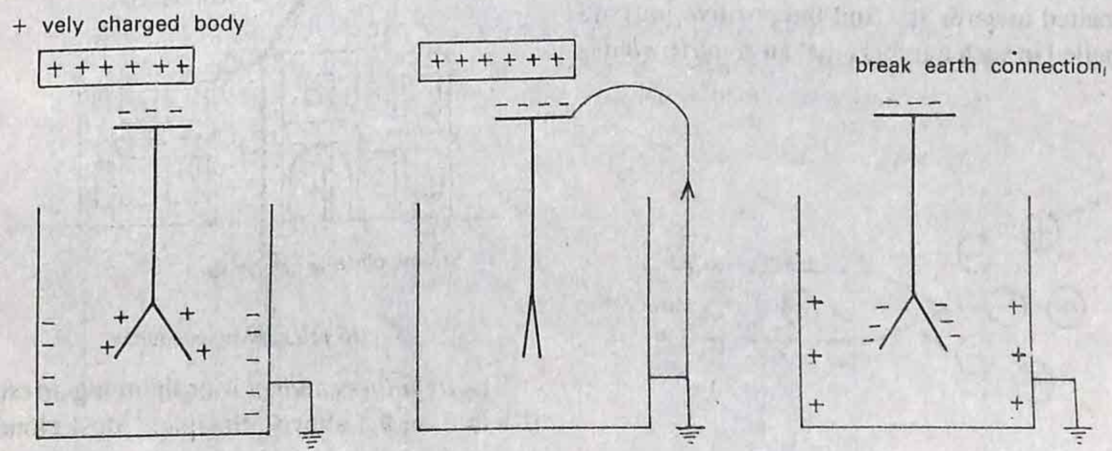
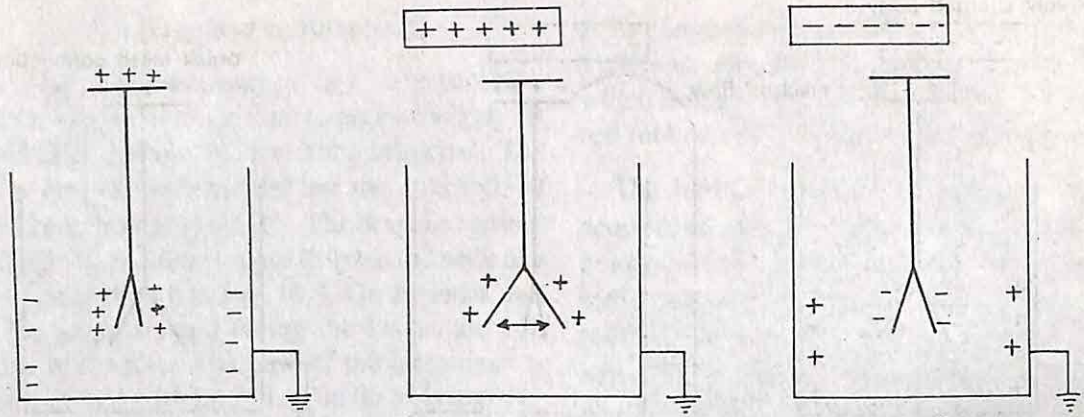


Fig. 10.8 Charging the electroscope negatively



+ vely charged electroscope increase in divergence decrease in divergence

Fig. 10.9 Detecting the nature of charge on a body

ACTION OF POINTS

By testing conductors of all shapes, it can be shown that the greatest charge resides where the radius of curvature is the least. The charge per unit area of a surface is called its *charge density*. Hence, a point which has a very small radius of curvature, accumulates a large amount of charge. This charge does not remain on the point for long, for the atmospheric air contains a number of positive and negative ions. The ions of the same sign as the charge on the conductor will be repelled while those of the opposite sign will be attracted towards it. If the point is positively charged, as shown in figure, the negative ions are attracted towards it. And the positive ions are repelled in such numbers that an *electric wind* is formed of ions rapidly moving away from the point carrying much of the positive charge away from it. At the same time, the ions moving towards it, neutralize it, since they are of opposite sign. Hence, a pointed conductor loses its charge quickly. The converse of this is also true, i.e., a point also collects charge surrounding it.

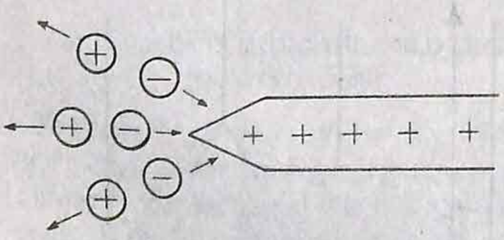


Fig. 10.10 An electric wind

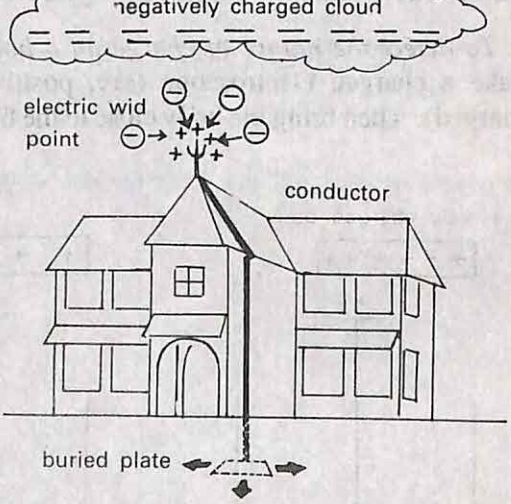


Fig. 10.11 Lightning conductor

The *lightning conductor* or lightning arrestor is based on the above principle. Most clouds, especially thunder clouds, are electrically charged. If such a charged cloud drifts over a building, the building and the earth around it become highly charged by induction. A discharge (lightning flash) may take place between the building and the cloud above, and such a large quantity of charge passing through a building would damage it. To prevent this a lightning conductor is fitted to the building. This is usually a thick copper strip fixed to an outside wall, reaching above the highest part of the building, and ending in one or more sharp spikes.

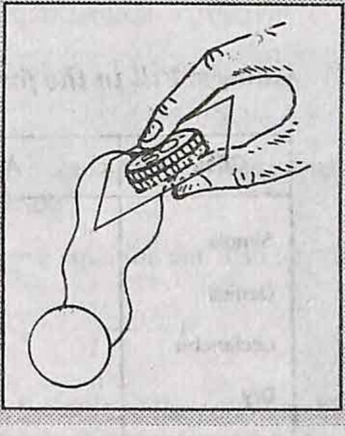
The lower end is connected to a copper plate buried in the earth. The electric wind created near the pointed end of the lightning conductor will discharge the building without a flash occurring.

10.2 Electricity in motion– current electricity

For most of us, electrical energy is supplied from the mains, i.e., we just switch on a light or a fan, or a T.V. set and we are provided with electrical energy. Many appliances such as a torch, a transistor set, cameras, get their energy from batteries or dry cells.

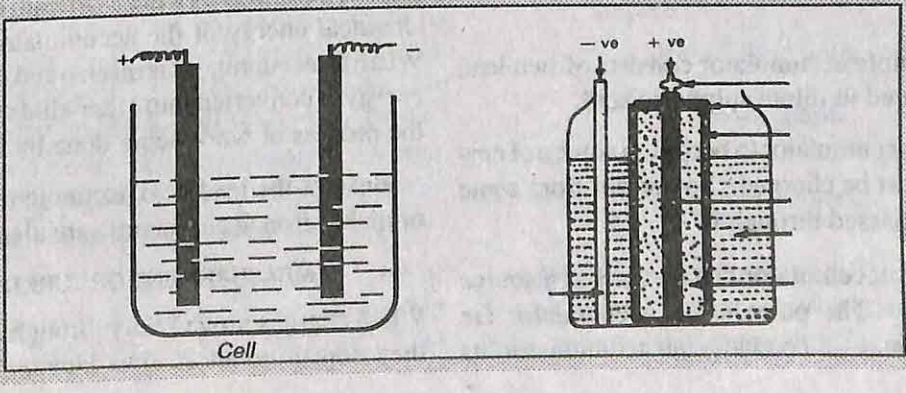
Activity 3: *A simple cell made from two coins.*

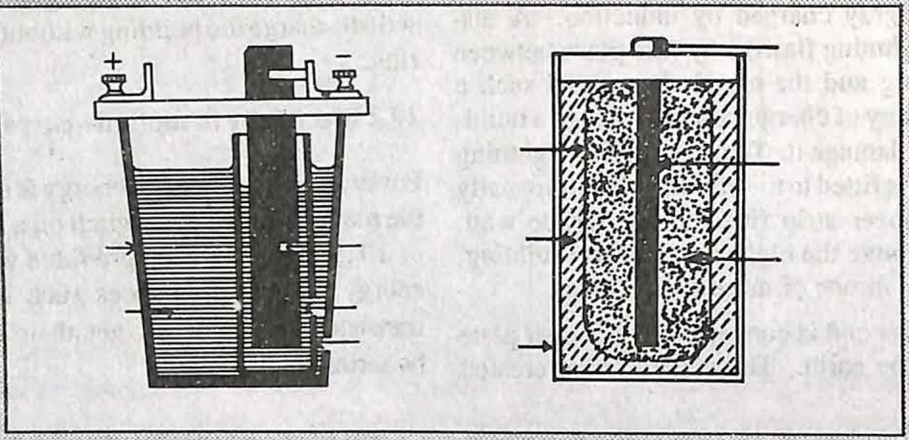
Take two coins made of different metals. Clean them well with steel wool or fine sand paper. Fold some paper towelling or blotting paper into a pad so that it is slightly larger than the coins. Soak the blotting paper in salt water. Place one coin on top of the pad and the other underneath. Hold them between your thumb and finger. Connect both leads of a sensitive galvanometer to the coins and watch the deflection.



You have already learnt that one of the first sources of electrical energy is the simple cell. You have also learnt about other cells like the Leclanche cell and the dry cell.

Activity 4: *Given below are diagrams of several cells. Which of them is a simple cell and which are primary cells? Label the different parts of the cells. Also state which of them is a Voltaic cell and which is a Leclanche cell.*





Activity 5: *Fill in the form given below:*

CELL	ADVANTAGE	DISADVANTAGE
Simple		
Daniell		
Leclanche		
Dry		

STORAGE BATTERY

Apart from primary cells there is another class of cells which can be recharged after they have been used, by passing current through them. They are also known as *storage cells* or *accumulators*.

The simple accumulator consists of two lead plates placed in dilute sulphuric acid.

For an accumulator to become a source of current, it must be charged. So current from some source is passed through it.

A charged accumulator can be used as a source of current. The poles of an accumulator are marked + and –. To charge an accumulator, its positive pole must be connected to the positive pole of the source, and its negative pole to the negative pole of the source.

When an accumulator is being charged, the electric current does work as a result of which the chemical energy of the accumulator increases. When an accumulator is discharged, its chemical energy is converted into other kinds of energy in the process of work being done by the current.

Besides the lead-acid accumulators, alkaline or nickel-iron accumulators are also used.

MEASUREMENT OF CURRENT

When charges move freely through a conductor they constitute an *electric current*. A charge moves through a conductor only when there exists a *potential difference* between the ends of the conductor. The unit in which electric current is measured is called the *ampere* after the scientist who established the laws relating to the force between two conductors when a current passes through them.

In the SI system of units, the ampere is defined as *the steady current which, flowing in two infinitely long parallel conductors of negligible circular cross-section, placed a metre apart in vacuum, produces between the wires a force of 2×10^{-7} newtons per metre length of the conductor.*

The amount of charge flowing is called the quantity of electricity and is measured by a unit called the *coulomb*.

A coulomb is the quantity of electric charge that passes across a given point in a conductor when a current of one ampere flows through for one second.

Let I be the current flowing through a conductor for t seconds. The quantity of electric charge Q is given by

$$Q = I \times t \quad \text{coulombs}$$

Potential difference is measured in *volts*. In the SI system *a volt is the potential difference between two points, if the work done in conveying 1 coulomb of charge from one point to another is one joule.*

OHM'S LAW

As mentioned earlier, for an electric current to flow through a conductor a potential difference should exist between its ends. Experiments to study the relationship between potential difference and current flowing were done by George Simon Ohm, a physics teacher. He deduced the following law which is known as *Ohm's law*.

The current passing through a conductor at constant temperature is directly proportional to the potential difference between its ends. If the

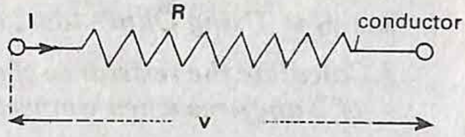


Fig. 10.12 Ohm's law

potential difference between the two ends of a conductor is V volts, and the current flowing through it is I amperes, then

$$\text{potential difference} \propto \text{current}$$

$$V \propto I$$

$$\text{or } V = IR$$

where R is a constant known as the resistance of the conductor.

The above equation can also be written as

$$\frac{V}{I} = R$$

Hence, the ratio of the potential difference to the current is the resistance of the conductor measured in a unit called the *ohm* (Ω).

In the SI system, the ohm is the resistance of a conductor through which a current of one ampere flows when the potential difference between its ends is one volt.

$$\frac{\text{volts}}{\text{ampere}} = \text{ohms}$$

$$V = IR \quad \text{volts}$$

$$R = \frac{V}{I} \quad \text{ohms}$$

$$I = \frac{V}{R} \quad \text{amperes}$$

For practical measurement of different electrical quantities for different electrical circuit connections, we use resistances of different forms.

Activity 6: *Using Ohm's law, do the following problems:*

1. *Calculate the resistance of a light bulb which carries a current of 2 amperes when connected to a 110 volt circuit.*
2. *What is the resistance of a flash light bulb which carries a current of 0.50 amperes when connected in series with a 6.0 volt battery?*
3. *How much current does a 36 ohm resistance draw when operated on a 120 volt line?*
4. *A resistance of 3 ohms has a current of 4 amp. flowing through it. What is the potential difference applied?*

Ans: (1) 55 ohms. (2) 12 ohms. (3) 3.33 amp. (4) 12 volts.

BATTERY OF CELLS

In order to increase the strength of the current or of potential difference, cells are sometimes arranged in groups, called batteries. There are in general two methods of grouping cells,
1) in series, and 2) in parallel.

1. Cells in series: Cells are said to be connected in series when the positive terminal of the first cell is connected to the negative terminal of the second, the positive of the second to the negative of the third and so on.

If there are *n* cells in series, and if the internal resistance of the cell *B* is very small compared to the external resistance *R*, then it can be shown that the current

$$I = \frac{nE}{R + nB} \quad \text{and since } B \text{ is negligible,}$$

$$I = \frac{nE}{R}$$

i.e., the potential difference across *R* is the sum of the e.m.fs of all the *n* cells each of e.m.f *E* volts. Hence, the maximum current is obtained when cells are connected in series, if the internal resistance is low.

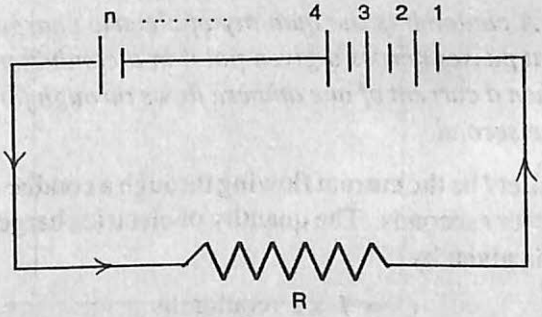


Fig. 10.13 Cells in series

2. Cells in parallel: Cells are said to be connected in parallel when all the positive terminals are connected together to form a positive plate and all the negatives are connected together to form a negative plate of the battery. Let *n* similar cells each of e.m.f. *E* volts and internal resistance *B* be connected in parallel. It can be shown that the current in the circuit is given by

$$I = \frac{nE}{B + nR}$$

and if *R* the external resistance is very small as compared to the internal resistance *B*, then

$$I = \frac{nE}{B}$$

Hence when the internal resistance of the cell is large compared to the external resistance R, the cells should be connected in parallel to obtain the maximum current.

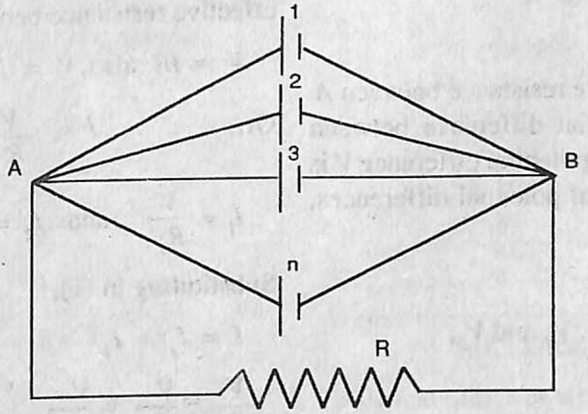


Fig. 10.14 Cells in parallel

Activity 7: *Draw circuit diagrams showing how 5 cells each of e.m.f. 2 volts may be connected 1) in series, and 2) in parallel in order to pass a current through a resistance R.*

If R = 2.5 ohms for (1), calculate the current.

If B = .05 ohms for (2), calculate the current.

RESISTANCES IN SERIES AND PARALLEL

You have already learnt that when a current of I amperes flows between the two ends of a conductor having a potential difference of V volts, then by Ohm's law,

$V = IR$

where R is the resistance of the conductor measured in ohms.

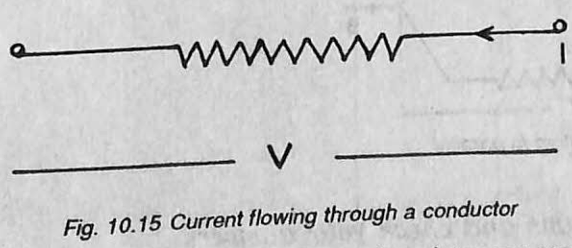


Fig. 10.15 Current flowing through a conductor

Resistances in series: Several resistances are said to be joined in *series* when they are arranged so that an electric current flows through them one after another. Let two resistances R_1 and R_2 be connected in series. Resistance R_1 is connected between the points A and B, and resistance R_2 is connected between B and C. Let V_1 be the potential difference across R_1 and V_2 be the potential difference across R_2. Then by

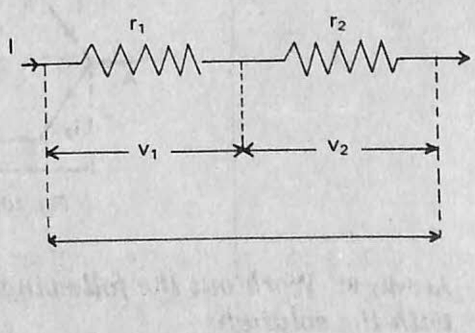


Fig. 10.16 Resistors in series

Ohm's law,

$$V_1 = IR_1 \text{ and}$$

$$V_2 = IR_2 \quad ..... (1)$$

Let R be the effective resistance between A and C, then the potential difference between them $V = IR$. The total potential difference V is the sum of the individual potential differences, i.e.

$$V = V_1 + V_2$$

Substituting values of V, V_1 and V_2,

$$IR = IR_1 + IR_2$$

$$\text{or } R = R_1 + R_2$$

Thus, the effective resistance of two resistances in series is equal to the sum of the individual resistances. If there are n equal resistances R connected in series, then the effective resistance will be

$$R + R + R \text{ .... } n \text{ times } = nR$$

Resistances in parallel Resistances are said to be connected in *parallel* when one end of each resistance is connected to one point, and the other end of each resistance is connected to another point. (Fig. 10.17). The current I, on entering at A, splits into two parts I_1 and I_2 which join up again at B to give I.

$$\text{Hence,} \quad I = I_1 + I_2 \text{ .... } (1)$$

Let V be the potential difference between the points A and B. Then, by Ohm's law, if the effective resistance between A and B is R

$$V = IR \text{ also, } V = I_1R_1 \text{ and } V = I_2R_2$$

$$\text{Or,} \quad I = \frac{V}{R}$$

$$I_1 = \frac{V}{R_1} \quad \text{and} \quad I_2 = \frac{V}{R_2}$$

Substituting in (1),

$$I = I_1 + I_2$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\frac{I}{R} = \frac{I}{R_1} + \frac{I}{R_2}$$

Or, when resistances are connected in parallel, the reciprocal of the effective resistance is equal to the sum of the reciprocals of the individual resistances. If n resistances of resistance R are each connected in parallel, the reciprocal of the effective resistance is

$$\frac{I}{R} + \frac{I}{R_1} + \text{ ... } n \text{ times}$$

$$= n \times \frac{1}{R}$$

$$= \frac{n}{R}$$

$$\therefore \text{ Effective resistance } = \frac{R}{n}$$

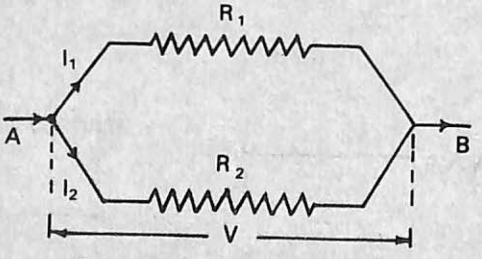


Fig. 10.17 Resistors in parallel

Activity 8: *Work out the following problems and check your answers with the solutions.*

Example 1: *Find the effective resistance of two resistances of 2 ohms and 3 ohms when they are connected in (1) series and (2) parallel.*

(a) $R_1 = 2 \qquad R_2 = 3$

$$R = R_1 + R_2 = 2 + 3 = 5$$

(b) $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\text{or } R = \frac{R_1 R_2}{R_1 + R_2} = \frac{2 \times 3}{2 + 3} = \frac{6}{5}$$

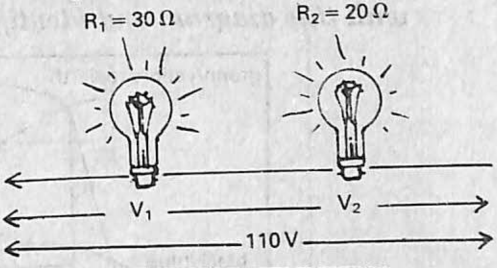
$$= 1.2\,\Omega$$

Example 2: *Two lamps of resistances 30 ohms and 20 ohms are connected in series in a 10 volt circuit. Calculate 1) the total resistance, 2) the current in the circuit, 3) the voltage drop across each lamp.*

(a) $$R = R_1 + R_2$$
$$= 30 + 20 = 50\,\Omega$$

(b) $$V = 110\,V, \quad R = 50 \qquad I = ?$$
$$I = \frac{V}{R} = \frac{110}{50} = 2.2 \text{ amp.}$$

(c) $$V_1 = IR_1 \qquad V_2 = IR_2$$
$$= 2.2 \times 30 \qquad = 2.2 \times 20$$
$$V_1 = 66 \text{ volts} \quad V_2 = 44 \text{ volts.}$$



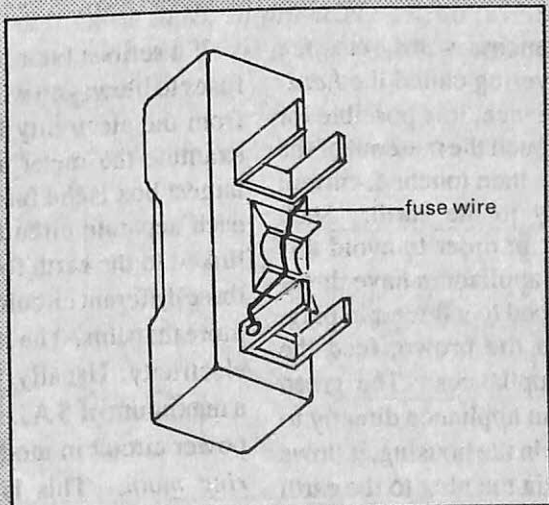
HOUSEHOLD CIRCUITING

Electrical cables or wires run through the whole house but all we can see are switches, sockets and cable ends for various appliances.

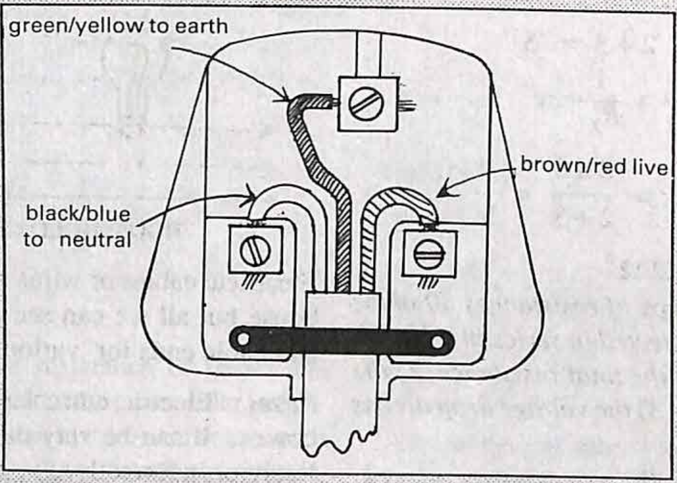
Fuses: Electric current is widely used in our homes. It can be very dangerous if used carelessly or incorrectly.

In designing any electrical circuit, care must be taken to ensure that no circuit carries too much current, as otherwise the conductor will get overheated. The heat developed is directly proportional to the square of the current. Hence,

Activity 9: *Find out where the fuses are in your home and, with the help of an adult, identify the fuse wire in them. Are there any other types of fuses? How are they different from this one?*



Activity 10: *Find out which appliances in your home have three-pin plugs. Examine the three pin plug of (say) the electric iron. Loosen the screw at the centre and remove the cover. Compare the placement of wires with this diagram and identify them.*



the wire should be able to carry the given current. To prevent fires on large currents through circuits, fuses are put in as safeguards. Each fuse consists of a length of metal alloy with a low melting point, such as tinned copper, placed into a porcelain carrier. If an excess current is drawn, the fuse wire will melt instead of harming the rest of the circuit.

Most electrical appliances, wires, etc. are placed in a protective covering called the *housing*. In an electrical appliance, it is possible for a wire to work loose and touch the material of the housing. If the housing is then touched, current could flow via the body to the earth. Such accidents could be fatal. In order to avoid this danger, the leads to most appliances have three-core cables. This is attached to a three-pin plug. Two cores, the blue and the brown, feed the electric current to the appliances. The green connects the housing of an appliance directly to the earth. If current flows in the housing, it flows along a good conductor via the plug to the earth giving protection to the user.

THE WIRING SYSTEM OF A HOUSE

The figure 10.20 shows a simplified picture of the wiring system in a house. The electrical supply from the power station is transformed to the correct voltage (240 V) at a local sub-station. It then travels underground to the house. The electricity board has its own meter at this point.

If a serious fault in your house causes all the fuses to blow, you will have to call an electrician from the electricity board to repair this. Next, examine the meter and the main switch. The largest box is the fuse or *distribution box* where each separate circuit has its *main* fuse, and is linked to the earth for safety. The figure shows three different circuits, though most houses have more than this. The lighting circuit uses the least electricity. Usually, it is wired and fused to take a maximum of 5 A, and may not be earthed. The power circuit in modern installations is called a *ring main*. This is because, as the diagram shows, each of the wires— *live, neutral* and *earth* — make a ring or circuit. Each socket is simply connected between the wires at the right place. Since this circuit needs to include heaters rated upto 3 kilowatts it is wired and fused for a maximum of 30 A and 13 A at any plug. Note that all points and lights are wired in parallel. The electric cooker has its own circuit because it may require upto 30 A.

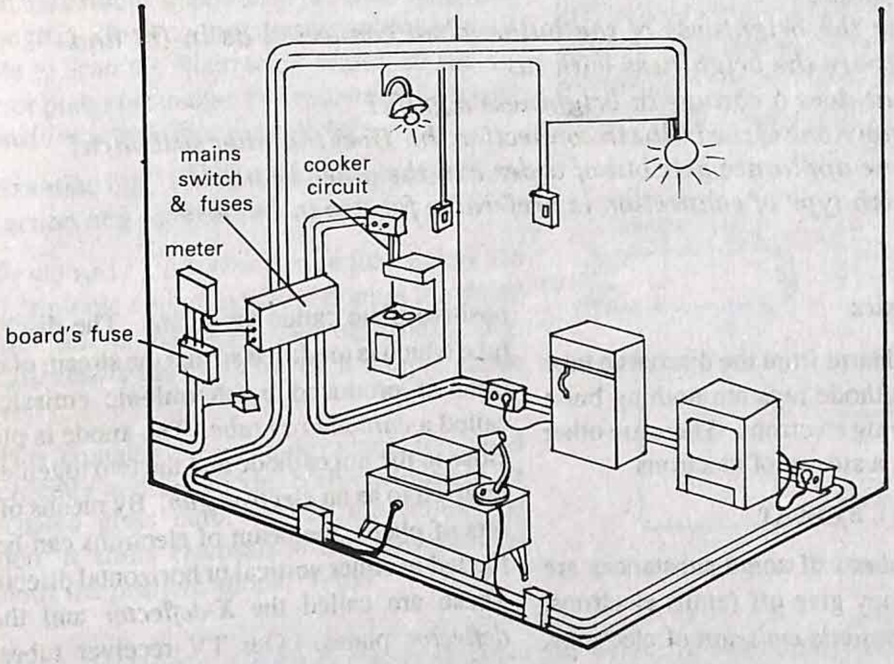
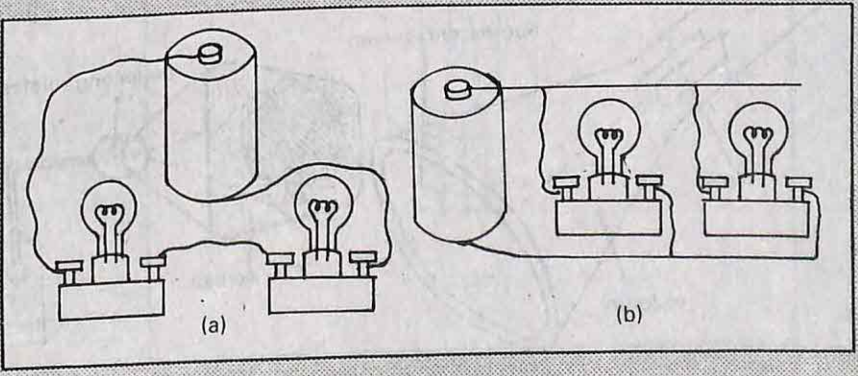


Fig. 10.18 Wiring system of a house

Activity 11: *Do this simple experiment to find out why electrical circuits in houses are in parallel and not in series .*

Take two flashlight bulbs with sockets and connect them first as in (a) in series, and then as in (b) in parallel, with a cell or battery as shown. Imagine each bulb to be a household appliance and the battery the main supply.



1. *Note the brightness of the bulbs when connected as in (a).*
2. *Remove one of the bulbs in (a). Does the other bulb glow?*
3. *In our homes, if one appliance does not work, will we be able to use the others?*
4. *Note the brightness of the bulbs when connected as in (b) and compare the brightness with (a).*
5. *What does a change in brightness signify?*
6. *Remove one of the bulbs in connection (b). Does the other still burn?*
7. *If one appliance gets out of order can the other be used?*
8. *Which type of connection is preferable for use in homes?*

10.3 Atomic Physics

You have already learnt from the discharge tube experiment that cathode rays are nothing but a stream of fast moving electrons. There are other ways of obtaining a stream of electrons.

1. BY HEAT

a. Cathode-ray tubes : If some substances are heated strongly, they give off (emit) electrons. This is called *thermionic emission* of electrons. If this stream of elections emitted by heat is to be made to flow, it must be attracted by some positive plate called an *anode*. The discharge tube which is modified so that the stream of electrons is produced by thermionic emission is called a *cathode ray tube*. The anode is placed close to the hot cathode and the two together are referred to as an *electron gun*. By means of two sets of plates, the beam of electrons can be deflected in either vertical or horizontal directions. These are called the *X-deflector* and the *Y-deflector* plates. Our TV receiver tubes are cathode ray tubes, one face of which is coated inside with some fluorescent material.

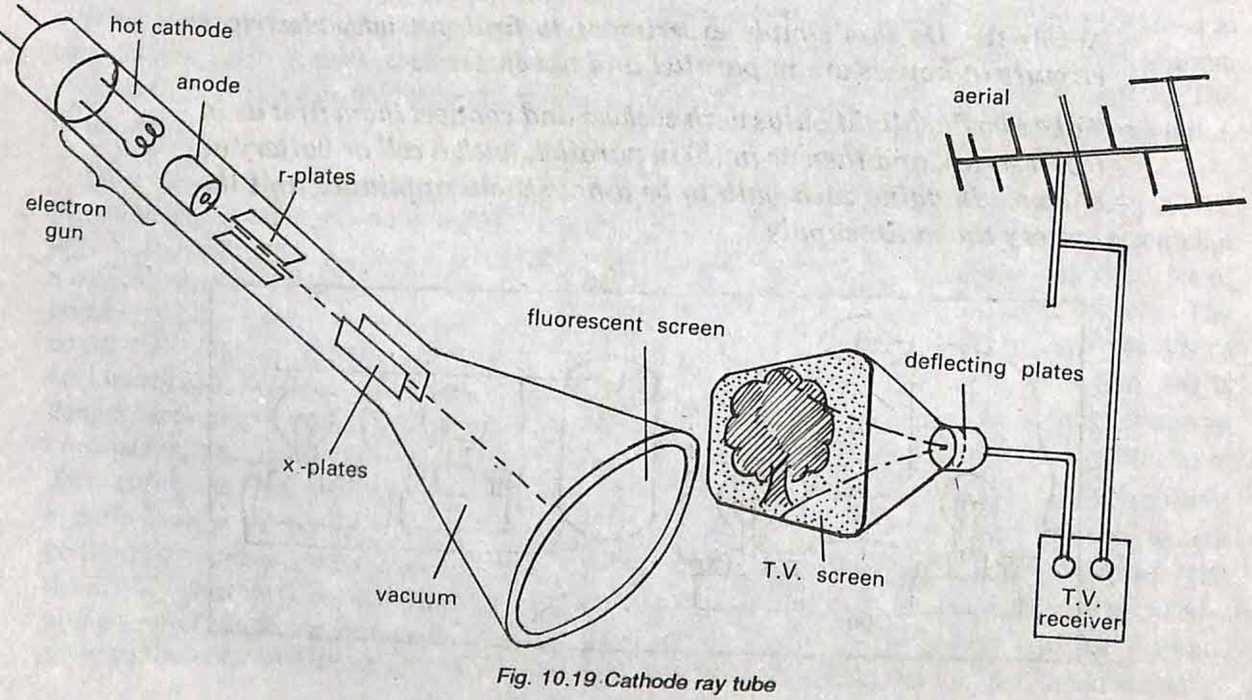


Fig. 10.19 Cathode ray tube

Radio waves carrying the television signals are passed through the receiving aerial causing varying currents to flow through the hot cathode of the receiver. The number of electrons emitted from the cathode depends on the current flowing through it. This varying current electron beam is made to scan the fluorescent screen by the deflector plates producing fluorescence of varying intensities which forms the picture.

Examine Fig. 10.19. It is a diagram to show the action of a cathode ray tube.

b. Diode valve : Another device that makes use of thermionic emission of electrons is the *diode valve* (diode meaning two electrodes/ Fig. 10.20). shows the structure of a simple diode valve.

This contains the cathode which is heated electrically and the anode, both enclosed in an evacuated glass bulb. When the cathode is heated, it emits electrons which are attracted towards the positive anode. Why?

Find out why it is called a *valve*.

Since current flows only when the anode is positive, i.e., in one direction, the diode is used as a *rectifier*, i.e., it converts alternating current to direct current and also as a *detector*, i.e., it separates the *audiowaves* (audio frequency radio waves) from the *carrier waves* (high frequency radio waves).

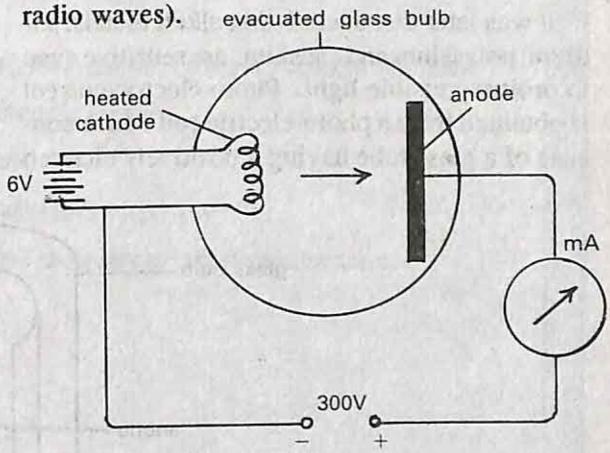
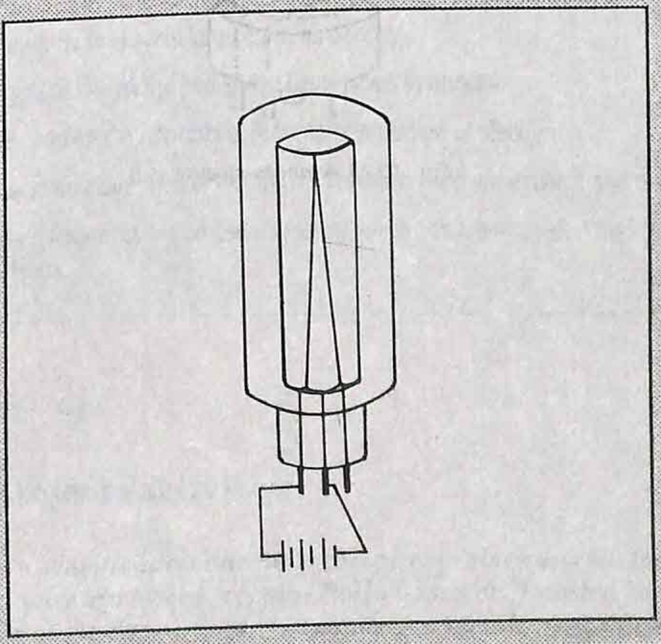


Fig. 10.20 Diode valve

Activity 12: *Given below is a diagram showing the construction of a diode. Compare it with Fig 10.23 and label the parts.*



2. BY LIGHT

About one hundred years ago, scientists found that when ultraviolet radiations fall on a zinc plate, electrons are emitted from the surface of the zinc plate. Thus electrons were shown to be emitted when light falls on certain substances. This is called photo-emission of electrons.

It was later discovered that alkali metals, sodium, potassium and caesium, are sensitive even to ordinary visible light. Photo-electric current is obtained from a photo-electric cell which consists of a glass tube having a positively charged anode at its centre which attracts electrons. The rate of emission is proportional to the amount and nature of light falling on the metal.

Uses of photo-cell : The photo-cell has several useful applications, a few of which are given below :

1. in control circuits which are used for open and close doors,
2. in burglar alarms,
3. to control dangerous machinery, and
4. to reproduce sound for motion pictures.

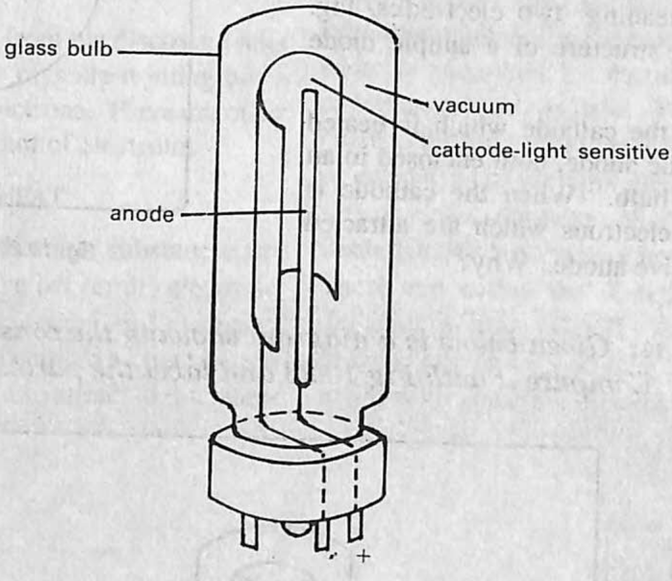


Fig. 10.23 A photo-electric cell

Basic concepts

1. According to the electronic theory, a body becomes charged if it gains (negative charge) or loses (positive charge) electrons.
2. Materials in which electrons can move readily are called conductors and those in which electrons cannot readily move are called insulators.
3. The gold leaf electroscope is an instrument for detecting the presence and nature of charge on a body.
4. Lightning arrestors are based on the principle of the action of points.
5. The flow of electric charge constitutes an electric current.
6. The Voltaic cell is a simple cell while Leclanche and Daniel cells are primary cells.
7. Lead-acid accumulators and nickel-iron accumulators are secondary cells or storage batteries.
8. The units of measurement of

   current - amperes
   potential difference - volts
   electric charge - coulombs
   resistance - ohms

9. If two resistances are connected in series, their effective resistance $R = R_1 + R_2$.
10. If two resistances are connected in parallel, their effective resistance R is given by

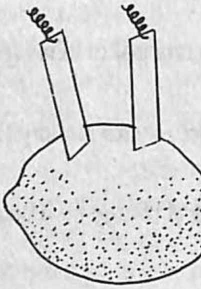
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

11. Fuses are used as safeguards to prevent large currents or fires.
12. The household wiring system has all the points and lights wired in parallel.
13. Cathode ray tubes are based on the principle of thermionic emission of electrons.
14. Diodes are based on thermionic emission of electrons. They are used as rectifiers and detectors.
15. When light waves of certain frequency fall on certain metals, electrons are emitted. This is known as photo-electric emission of electrons.

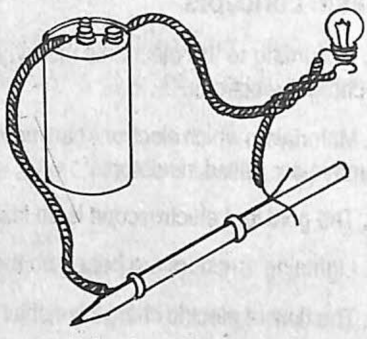
Some suggested projects/activities

1. *Connect one wire from a sensitive galvanometer to a piece of zinc cut from the can of a used dry cell. Connect the other wire to a piece of copper. Roll a lemon on the table, pressing it with your hand to break up some of the tissue inside. Push the two metal strips through the skin of the lemon, making sure they do not touch (see diagram). Observe the needle.*

Try this experiment using a potato. Does the distance between the plates affect the meter reading?

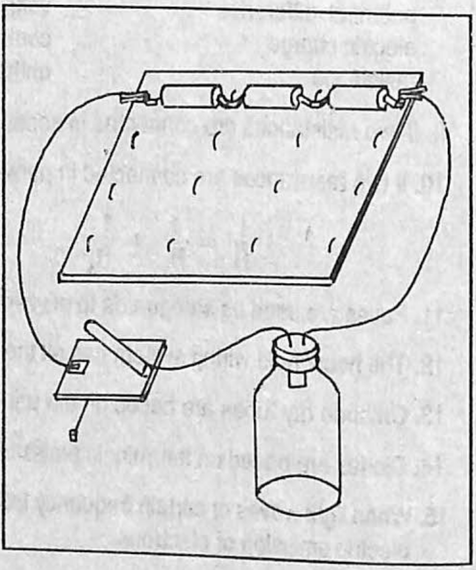


Electricity from a lemon



A simple switch

2. *A simple switch can be made by fastening the end of a piece of bell wire to a pencil with two rubber bands as shown in the diagram. A second wire spliced under it makes a suitable connection.*



3. *Push the ends of two pieces of bell wire through a flat cork that fits a small bottle. A suitable flat cork can be made by cutting off the end of a longer cork, or a two-hole rubber stopper may be used instead. Wind the ends of a strand of very thin iron wire around the projecting ends of the copper wires and insert the cork into a bottle (see diagram). The result will serve as a crude model of an electric lamp. Connect the electric lamp model into a circuit with one or more dry cells and a switch. Close the switch until the fine wire (filament) begins to glow, then open the switch again. With care, the lamp can be lighted several times before the filament is consumed, but finally the heated iron wire combines with the oxygen of the air inside the bottle and burns away.*

Why do commercially made lamps burn for a longer time?

REVISION

I. Choose the correct answer.

1. When a current flows through a conductor, its resistance
   a. increases with the current. b. decreases with increase of current. c. remains constant. d. none of the above.

2. If a current of 0.1 amperes flows through a resistance of 10 ohms, the potential difference is
   a. 1 volt. b. 100 volts. c. 0.01 volts.
3. In a resistor,
   a. volts x ohms = amperes.

   b. $\frac{\text{ohms}}{\text{volts}}$ = amperes.

   c. $\frac{\text{volts}}{\text{ohm}}$ = amperes.
4. The charge density of a conductor is most
   a. when the radius of curvature is large. b. at pointed ends. c. on the plane surface. d. whatever the shape.
5. The Leclanche cell is a
   a. storage battery. b. simple cell. c. secondary cell. d. primary cell.
6. When two conductors are connected in parallel, the effective resistance
   a. increases. b. decreases. c. remains the same. d. none of the above.
7. The cathode ray tube is based on
   a. thermionic emission. b. electrostatics. c. Ohm's law. d. photo-electric emission.
8. By touching a positively charged body with the hand
   a. the positive charges flow to the earth. b. negative charges flow from the hand to the charged body. c. negative charges flow from the hand to the body. d. negative charges flow from the earth to the body.
9. The gold leaf electroscope is used for
   a. producing electric charges. b. storing electric charge. c. detecting electric charge. d. charging a body.
10. When a negatively charged body is brought near the disc of a negatively charged electroscope, the leaves
    a. diverge more. b. come together. c. remain in the same position.
11. The end of a lightning conductor should be
    a. rounded. b. pointed. c. of any shape.

II. Fill in the blanks.

1. In electrostatic induction the end of the conductor nearest to the charged body is charged with _________ kind of charge.
2. If a charged body is brought near the disc of an uncharged gold leaf electroscope, the leaves _________.
3. An _________ in divergence occurs when the charge on the electroscope and the body are of the same kind.
4. An _________ is created around a pointed charged conductor.
5. A _________ is a method of storing a large quantity of electricity in a small space.
6. Ohm's law tells us how the current in a conductor depends on the _________ applied and on the _________ of the conductor.

7. According to Ohm's law, the formula for
current = ________ (in words).
I = ________ (in symbols).
amperes = ________ (in units).

8. A resistance of 2 ohms is connected to a source of 4 volts, the current flowing is ________ amperes. If connected to a source of 1 volt, the current is ________ amperes.

9. The Voltaic cell is a ________ cell.

10. The Daniell cell is a ____________ cell.

11. The lead acid battery is a ________ cell.

12. If 5 cells each of e.m.f. 2 volts is connected in series, the combined e.m.f. is ________.

13. If two resistors are connected in ________, the effective resistance decreases.

14. If two resistors are connected in ________, the effective resistance increases.

15. ________ are used as safeguards in the electrical wiring of a house.

16. In a three pin plug, the ________ wire is connected to the earth.

17. In households, all the points and lights are wired in ________.

18. The diode is based on the principle of ________ emission of electrons.

19. ________ are used in burglar alarms.

III .State whether the following are true or false:

1. A body charged by induction has the same sign of charge as the charging body.
2. If a charged body is brought near a second body, the second body is charged by conduction.
3. Two oppositely charged bodies attract each other.
4. Substances which allow electrical charges to flow easily through them are called conductors.
5. A lightning rod must have no connection with the ground.
6. The charges on a body are concentrated on that part of the body which has the greatest curvature.
7. A positively charged cloud induces a negative charge in the ground immediately under it.
8. Ohm's law holds good if the temperature remains constant.
9. The resistance of a conductor increases with the current flowing through it.
10. Potential difference between the ends of a conductor is directly proportional to the current flowing through it.
11. The combined resistance of 4 ohms and 4 ohms in parallel is 1/2 ohm.
12. When three resistances are combined in parallel the potential across each is the same.

IV. Answer the following questions briefly:

1. How will you charge a body by conduction?
2. Explain the 'action of points.'
3. How will you detect the nature of charge on a body using the gold leaf electroscope?
4. How will you use the gold leaf electroscope to detect the presence of charge on a body?
5. State and explain Ohm's law.

6. Find the effective resistance of two resistances in series.
7. Find the effective resistance of two resistances in parallel.
8. Discuss how cells can be connected in series.
9. Discuss how cells can be connected in parallel.
10. Write short notes on
    (a) fuses. (b) three-pin plug. (c) photo-cells.

V . Answer the following questions in detail:

1. Explain how you will charge a body negatively by induction.
2. Describe a gold leaf electroscope. How will you charge it positively?
3. Explain the action of a lightning arrestor.
4. Describe the storage battery.
5. Give a brief account of the household wiring system.
6. Describe a cathode ray tube. How is it used in television sets?
7. Describe the construction and action of a diode valve. What are its uses?
8. Discuss the principle, construction and uses of the photo-cell.

VI. Problems:

1. What is the current that a 6 volt battery supplies when it is connected to a resistance of 2 ohms? (Ans. 3 amp)
2. When a 200 ohms resistance is connected to the mains, the current is 1.15 amps. What is the mains voltage? (Ans. 230 v)
3. Three resistances of 2 Ω, 3 Ω, 4 Ω, are connected in a) series and b) parallel. Find their combined resistance in each case. (Ans. a. 9 Ω b. 0.92 Ω)
4. Two lamps of resistance 50 Ω and 40 Ω are connected in series in a 110 volt circuit. Calculate (a) the total resistance, and (b) the current in circuit. (Ans. a. 90 Ω b. 1.22 amp.)
5. If two lamps of resistance 20 Ω and 4 Ω are connected in parallel in a 110 volt circuit, determine a) the effective resistance of the circuit, and b) the current through each lamp. (Ans. a. 13.3 b. 5.5 amp. 2.75 amp.)

VII. Match the following:

1. diode valve
2. Ohm's law
3. photo-cell
4. cathode-ray tube
5. gold leaf electroscope

a. reproduction of sound
b. detection of charge
c. Daniell cell
d. secondary cell
e. TV receiver
f. thermionic emission
g. three-pin plug

Observations :

I. DETERMINATION OF LEAST COUNT

Value of 1 main scale division = ... mm.

Number of divisions on vernier = ... div.

Length of vernier = ... mm.

Value of 1 vernier scale division = ... mm.

Least count = 1 M.S.D. – 1 V.S.D.

= ________ – ________

= .... mm = ... cm.

II. DETERMINATION OF ZERO CORRECTION

Zero error = ... div.

= .... mm (no. of div x least count).

Zero correction = ... mm.

[Refer Chapter 1 for calculation of least count and zero error.]

PRACTICALS

EXPERIMENT 1: Vernier Callipers

Aim of the experiment : 1. To find the volume of a cuboid. 2. To find the area of largest face of the cuboid. 3. To find the surface area and volume of a cylinder.

[For description of callipers and determination of least count and zero correction see Chapter 1, page 3 & 4].

Apparatus required : Vernier callipers, a cuboid such as a glass slab, a cylinder.

Formulae used :

1. Volume of a cuboid $V = l \times b \times h$
   where l = length of cuboid
   b = breadth of cuboid
   h = height of cuboid.

2. Area of one face $A = l \times b$.

3. Volume of a cylinder $V = \pi r^2 h$
   where $\pi = 22/7$
   r = radius of cylinder
   h = height of cylinder

4. Surface area of sides of cylinder
   $A = 2\pi rh$

Procedure : A. CUBOID — VOLUME AND AREA

1. First determine the least count and the zero error of the vernier callipers and write their values as shown on the page on the left.
2. Place the glass slab between the jaws of the vernier callipers so that it is firmly gripped.
3. Note the reading on the main scale upto the zero of the vernier scale. This gives the main scale reading.
4. Note the division of the vernier coinciding with a main scale division and enter it into the tabular form.
5. Find the total reading as shown M S R + (V C x L·C).
6. Carry out the zero correction if any.

III. DETERMINATION OF VARIOUS LENGTHS:

Object	*Dimension*		*Main Scale Reading cm*	*Vernier Coincidence div*	*VC x LC cm*	*Total Reading MSR + (VC x LC) cm*	*Total Reading ± Zero correction cm*
Cuboid	*Length*	1					
		2					
		3					
	Breadth	1					
		2					
		3					
	Height	1					
		2					
		3					
Cylinder	*Diameter*	1					
		2					
		3					
	Height	1					
		2					
		3					

		Average values cm
Cuboid	Length	
	Breadth	
	Height	
Cylinder	Diameter	
	Height	

7. Repeat the above procedure twice placing different parts of the slab between the jaws.

8. Repeat steps 2 - 7 to calculate the breadth and height of the slab.

9. Calculate the volume of the cuboid after finding the average l, b and h.

B. CYLINDER — VOLUME AND AREA

Repeat the above procedure by placing first the diameter of the cylinder between the jaws and then the length. Tabulate your readings as before.

Calculations

I. Volume = $l \times b \times h$ cc

=

= = ... m^3

Area of one face = $l \times b$ sq. cm

=

= = ... m^2

II. Volume of cylinder = $\pi r^2 h$

$$r = \frac{\text{diameter}}{2}$$

Surface area of cylinder = $2\pi rh$

=

Result: 1. Volume of the given cuboid = ... cc

2. The area of its face = ... sq. cm

3. The volume of the cylinder = ... cc

4. The surface area of the cylinder = ... sq. cm

Observations :

I. DETERMINATION OF LEAST COUNT

Value of 1 pitch scale division = ... mm

Number of divisions on the head = ...

Number of rotations given =

Number of divisions moved on pitch scale = ... mm

$$\text{Pitch} = \frac{\text{Distance moved}}{\text{No. of rotations}}$$

= .... mm

= .... m

$$\text{Least Count} = \frac{\text{Pitch}}{\text{No. of divisions on head scale}}$$

=

= .... mm = ... m

II. DETERMINATION OF ZERO ERROR

Zero error = ... div.

= .... mm

Zero correction = ... mm.

III. DETERMINATION OF DIAMETERS

Object	*Dimension*		*Pitch Scale coincidence (PSR) mm*	*Head Scale Reading HSC div*	*Total Reading (TR) PSR + (HSC x LC) mm*	*Corrected Reading TR ± ZC*
Wire	*diameter*	1				
		2				
		3				
		4				
		5				
Lead shot	*diameter*	1				
		2				
		3				
		4				
		5				

Average diameter of wire = ... mm

= .... m

Average diameter of lead shot = ... mm

= .... m.

Note : Instead of lead shots the thickness of a thin glass plate may be determined.

EXPERIMENT 2 : Screw Gauge

Aim of the experiment : To measure
(i) the diameter of a wire,
(ii) the diameter of a lead shot using a screw gauge.

Apparatus required : Screw gauge, a small length of wire, lead shot.

Procedure :

1. First find out the pitch of the screw and calculate its least count.
2. Next examine the screw gauge for zero error and determine the zero correction as described in the text.
3. Then rotate the screw backwards and insert the object (wire) in the space between the plane surfaces.
4. Rotate the screw till the wire is gently gripped between the two faces and the ratchet starts slipping.
5. Note the complete divisions on the pitch scale (PSR).
6. Note the division on the head scale coinciding with the reference line (HSR).
7. Tabulate your reading as shown on the opposite page and carry out the zero correction.
8. Repeat the above procedure at 5 different places of the wire and fine the average diameter.
9. Repeat the experiment replacing the wire with a lead shot.

Result:

1. The diameter of the wire = ... mm
= .... m

2. The diameter of the given lead shot = ... mm
= .... m.

Observations :

Load in pans gms		*Turning points*		*Mean of turning points*		*Resting point*	*Correct mass of the body gm*
Left	*Right*	*Left*	*Right*	*Left*	*Right*		
Nil	*Nil*					*Z.R.P.* *(a)*	
Given body	*W gms (say)*					*(b)*	
Given body	*W± .01 gm*					*(c)*	

EXPERIMENT 3 : Physical Balance

Aim of the experiment : To measure the mass of a body correct to a centigram using a physical balance.

Apparatus required : A physical balance, a weight box including fractional weights, the object to be weighed such as a glass stopper.

Procedure :

1. Observe if the balance is level. If not, adjust it by working the screws at the base till the plumb line hangs centrally over the index.
2. Gently turn the handle to the right so that the beam oscillates. The beam should oscillate almost equally on both sides.
3. To find the zero resting point note down five consecutive turning points, three on the left and two on the right.
4. Find the mean of the three 'left' turning points and the mean of the two 'right' turning points. The mean of these two is the zero resting point — (a).
5. Place the given body in the left pan and weights in the right pan so that the pointer swings nearly equal number of divisions on both sides.
6. Now find the resting point again. Let it be (b).
7. If (b) is more than (a), add 10 mg to the weights in the right pan and again find the resting point (c). If (b) is less than (a) then remove 10 mg and find the resting point (R.P) again (c).
8. See which resting point is closer to (a). The weights in the left pan corresponding to that resting point gives the weight of the body correct to a centigram.

Result : The weight of the given body correct to a centigram = ... gm

= .... kg.

I. DETERMINATION OF THE RADIUS OF THE BOB

Reading on metre scale of 1st face of block = ... cm (a)
Reading on metre scale of 2nd block = ... cm (b)
Diameter of block d = (b) – (a)
= .... cm
Radius of block r = d/2
= ....
= .... cm.

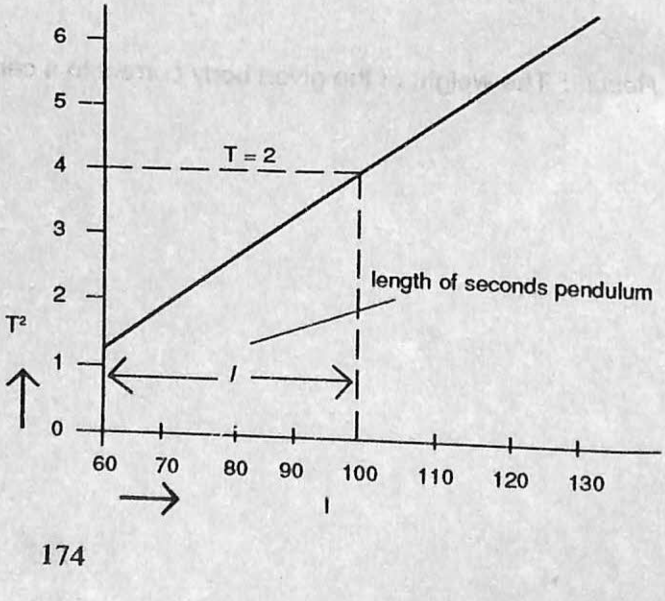
II. DETERMINATION OF TIME PERIOD.

S.No.	Length of the pendulum cms	Time for 20 oscillations			Time period T^2 s	T^2 s^2	l/T^2 cm/s^2
		1	2	Mean			
1	60						
2	70						
						Mean l/T^2	

Calculations:

mean l/T^2 = ...
$g = 4 \times \pi^2 \times l/T^2$
$= 4 \times (3.14)^2 \times l/T^2$
= .... cm/s^2
= .... m/s^2

Graph



EXPERIMENT 4 : Simple Pendulum

Aim of the experiment : To determine the value of g, the acceleration due to gravity using a simple pendulum.

Apparatus required : Metal bob, thread, stand, split cork, stop clock, metre scale, blocks of wood or vernier callipers.

Formula used : The acceleration due to gravity is given by the relation

$$g = \frac{4\pi^2 l}{T^2}$$

where l = length of the pendulum and T is the time period of oscillation of the pendulum.

Procedure:

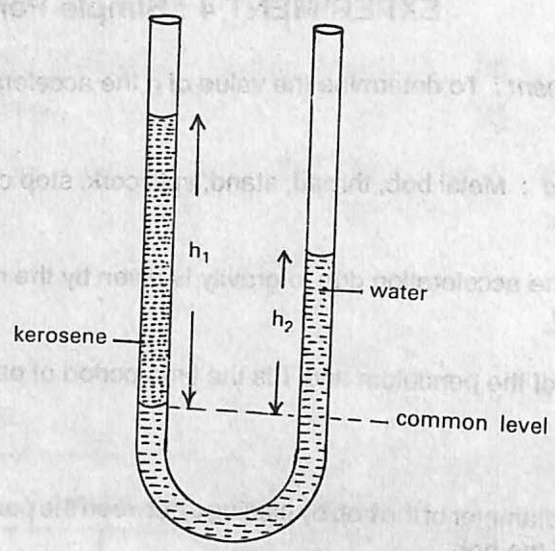
1. Measure the diameter of the bob by placing it between the parallel faces of two blocks. Calculate the radius (r) of the bob.
2. Suspend the bob with the thread between the two pieces of split cork from the clamp in the stand.
3. Now adjust the length of the thread so that the distance between the point of suspension and the lower end of the bob is $(60 + r)$ cm. This makes the length of the pendulum to be exactly 60 cm.
4. Now displace the bob by pulling it gently to one side and find the time for 20 oscillations. To do this either clamp a pointer beneath the bob or make a mark with a chalk beneath it when it is at rest. As the bob crosses the mark in a particular direction – say left to right, start the stop clock. When the bob next crosses the mark in the same direction from left to right count one. In a similar way count 20 oscillations and stop the stop clock as soon as you count 20. Note the time for 20 oscillations.
5. Repeat the procedure for the same length.
6. Now alter the length of the pendulum to 70, 80, 90, 100, 110, and 120 cms successively finding the time for 20 oscillations in each case.
7. Record your observations in the tabular form and calculate the time for 1 oscillation, T.
8. Find T^2 and l/T^2 and enter the values in the tabular form.
9. Find the mean l/T^2 and substitute this value in the formula $4\pi^2 l/T^2$ and calculate 'g'.
10. Plot a graph of l against T^2 taking l on the x-axis and T^2 on the y-axis.
11. From the graph find the length of a seconds pendulum, i.e., for $T = 2$ sec.

Result : 1. The value of the acceleration due to gravity is = ... cm/s^2

= .... cm/s^2

2. The length of the seconds pendulum = ... cm

= .... m.



S.N.	Height of liquid column (h_1) cms	Height of water column (h_2) cms	$RD = \frac{h_2}{h_1}$
1			
2			
3			
4			
5			
		Mean $\frac{h_2}{h_1}$ =	

Calculations :

1. h_1 = ... cm h_2 = ... cm

$\frac{h_1}{h_2}$ = = ...

repeat this for all five readings.

2. Find the mean of h_2 / h_1

EXPERIMENT 5

Aim of the experiment : To determine the relative density of a liquid immicible with water such as kerosene.

Apparatus required : A U-tube fixed or clamped to a stand, a half metre scale, a beaker of kerosene, beaker of water.

Forumula: Relative density of liquid is given by

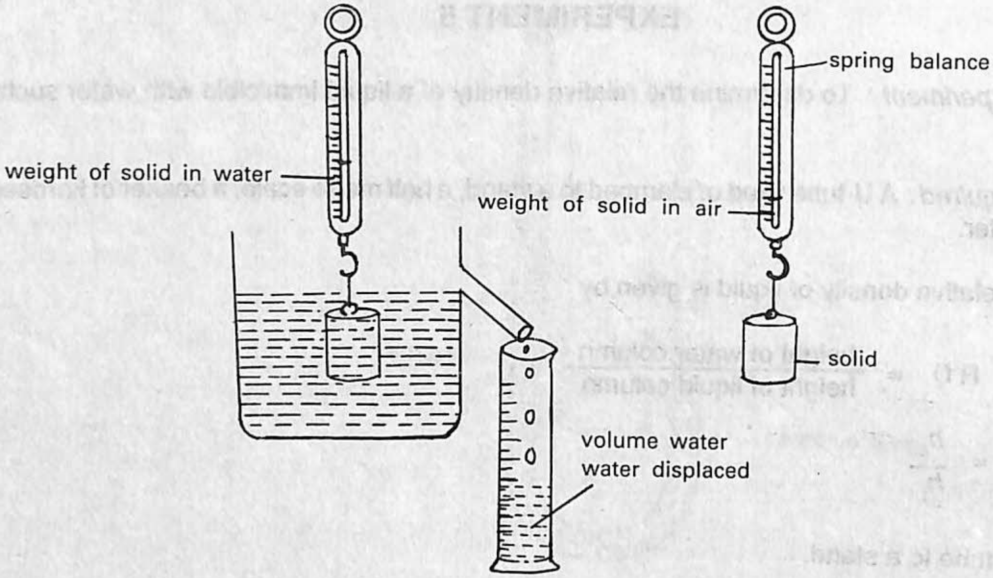
$$\text{R D} = \frac{\text{height of water column}}{\text{height of liquid column}}$$

$$\text{or,} \quad \text{R D} = \frac{h_2}{h_1}$$

Procedure :

1. Fix a U-tube to a stand.
2. Put a few drops of red or blue ink into the water in the beaker and pour it into the U-tube.
3. Now pour the kerosene, into one limb, using a small funnel so that the water, partly fills both the limbs.
4. Mark the common level on both the limbs, using a ruler as a reference.
5. Measure the heights h_1 and h_2 of liquid and water above the common level and tabulate your readings.
6. Repeat the experiment for different amounts of water and kerosene.

Result : The relative density of the given liquid = ...



S.No.	Spring balance reading for solid in		Loss of weight $w_1 - w_2$ gm	Volume of water displaced cc	Weight of water displaced gm
	Air w_1 gm	Water w_2 gm			
1					
2					
3					
4					
5					
			A		B

Note : 1 cc of water weighs 1 gm.

Inference : Since $W_2 < W_1$ the values in columns A and B are equal. Thus Archimedes principle is verified.

EXPERIMENT 6 : Archimede's Principle

Aim of the experiment To verify Archimedes Principle.

Apparatus required : A spring balance, metal cylinder, overflow jar, measuring cylinder.

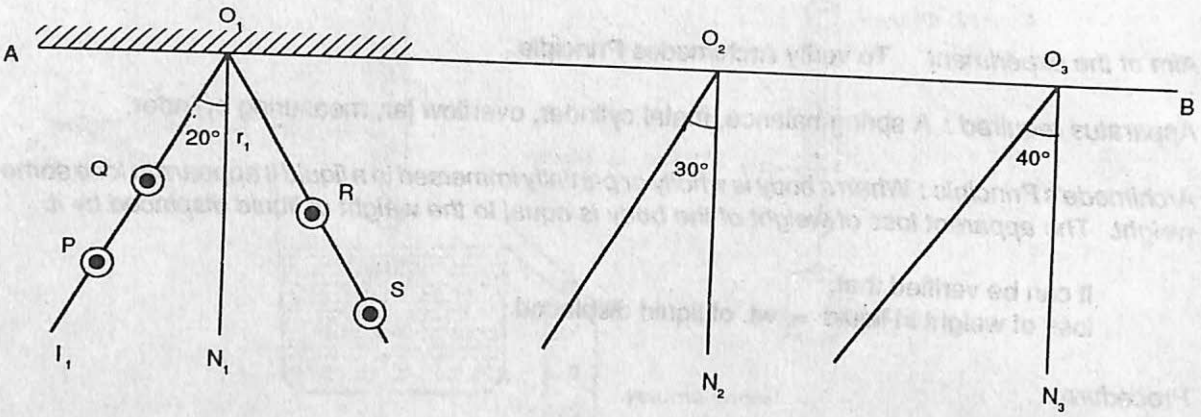
Archimede's Principle : When a body is wholly or partially immersed in a liquid it appears to lose some weight. The apparent loss of weight of the body is equal to the weight of liquid displaced by it.

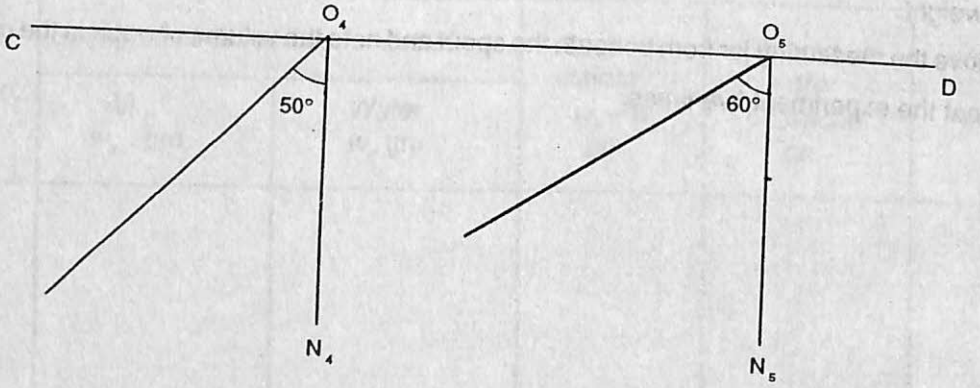
It can be verified that,
loss of weight in liquid = wt. of liquid displaced.

Procedure :

1. Suspend the cylinder from the spring balance and note its weight.
2. Fill water upto the spout in the overflow jar and place a measuring jar beneath the spout when drops of water cease to come out from the spout.
3. With the cylinder still suspended from the spring balance lower it into the overflow jar and note the weight.
4. Remove the measuring jar from beneath the spout and note the volume of water in the cylinder.
5. Repeat the experiment five times.

Observations :





S.N.	*Angle of incidence*	*Angle of reflection*
1	20°	
2	30°	
3	40°	
4	50°	
5	60°	

EXPERIMENT 7 : Laws of Reflection

Aim of the experiment : To verify the laws of reflection.

Apparatus requied : A plane mirror strip, white paper, drawing board, board pins, paper pins, protractor.

Laws of reflection : 1. The angle of incidence is equal to the angle of reflection. 2. The incident ray, the normal at the point of incidence and the reflected ray all lie in the same plane.

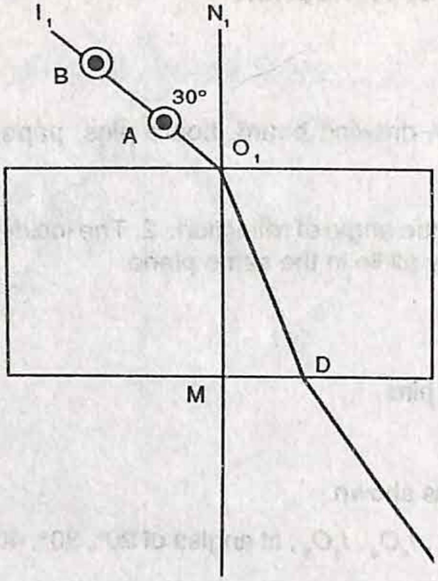
Procedure :

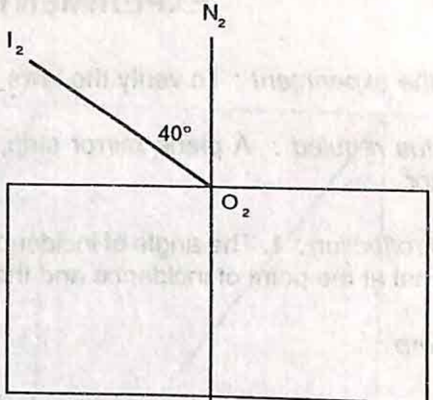
1. Fix the paper on the drawing board with the board pins.
2. Draw lines *AB* and *CD* on it.
3. Draw normals O_1N_1 , O_2N_2 , O_3N_3 , O_4N_4 , O_5N_5 , as shown.
4. Draw the direction of incident rays I_1O_1 , I_2O_2 , I_3O_3 , I_4O_4 , I_5O_5 , at angles of 20°, 30°, 40°, 50° and 60° with the normals respectively.
5. Place the mirror at O_1 with its reflecting surface towards the line I_1O_1 and its plane perpendicular to *AB.*
6. Fix two pins *P* and *Q* on line I_1O_1 at a distance of about 4 cm.
7. Place two other pins *R* and *S* so that the images of *P* and *Q* in the mirror P^1 and Q^1 and *R* and *S* appear to be in the same straight line. (When viewing through the mirror only the pin S should be visible, *R*, P^1 and Q^1 should be exactly behind it.)
8. Remove the mirror and pins and join *RS* and produce it backwards to meet *AB* at O_1.
9. Measure the angle of reflection $S\,O_1N_1$.
10. Repeat the procedure for other angles of incidence.
11. Tabulate your reading as shown.

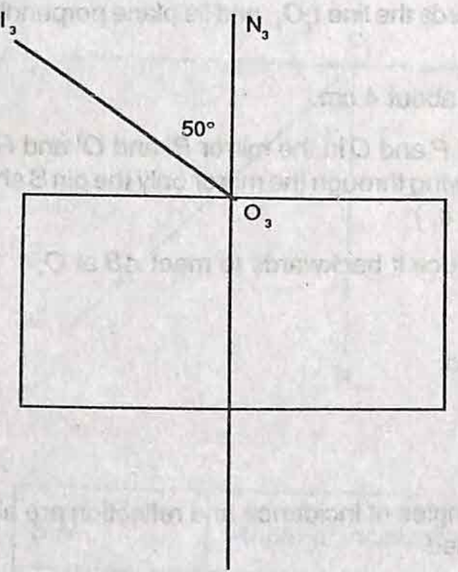
Result : 1. From the tabular form it is evident that the angles of incidence and reflection are almost equal. Thus the I Law of reflection is verified.

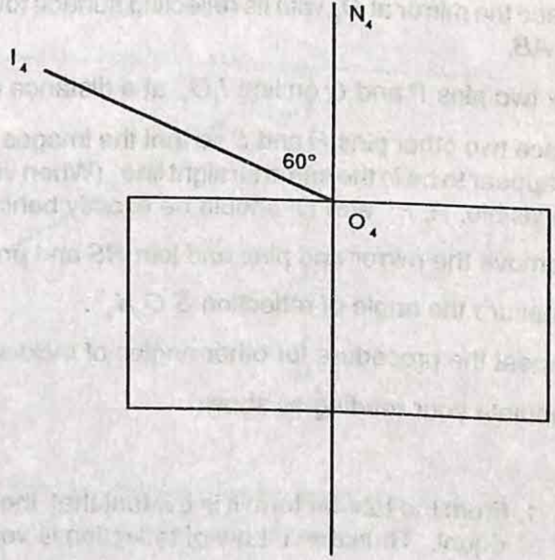
2. Since the incident ray, the normal at the point of incidence and the reflected ray all lie in the plane of the paper the II Law of reflection is verified.

Observations









Observations :

S.N.	*i*	*r*	*sin i*	*sin r*	$\frac{\sin i}{\sin r} = \mu$
1					
2					
3					
4					

EXPERIMENT 8 : Laws of Refraction

Aim of the experiment : To verify the laws of refraction.

Apparatus required : A glass slab, a white sheet of paper, drawing board, board pins, paper pins, protractor.

Laws of refraction :

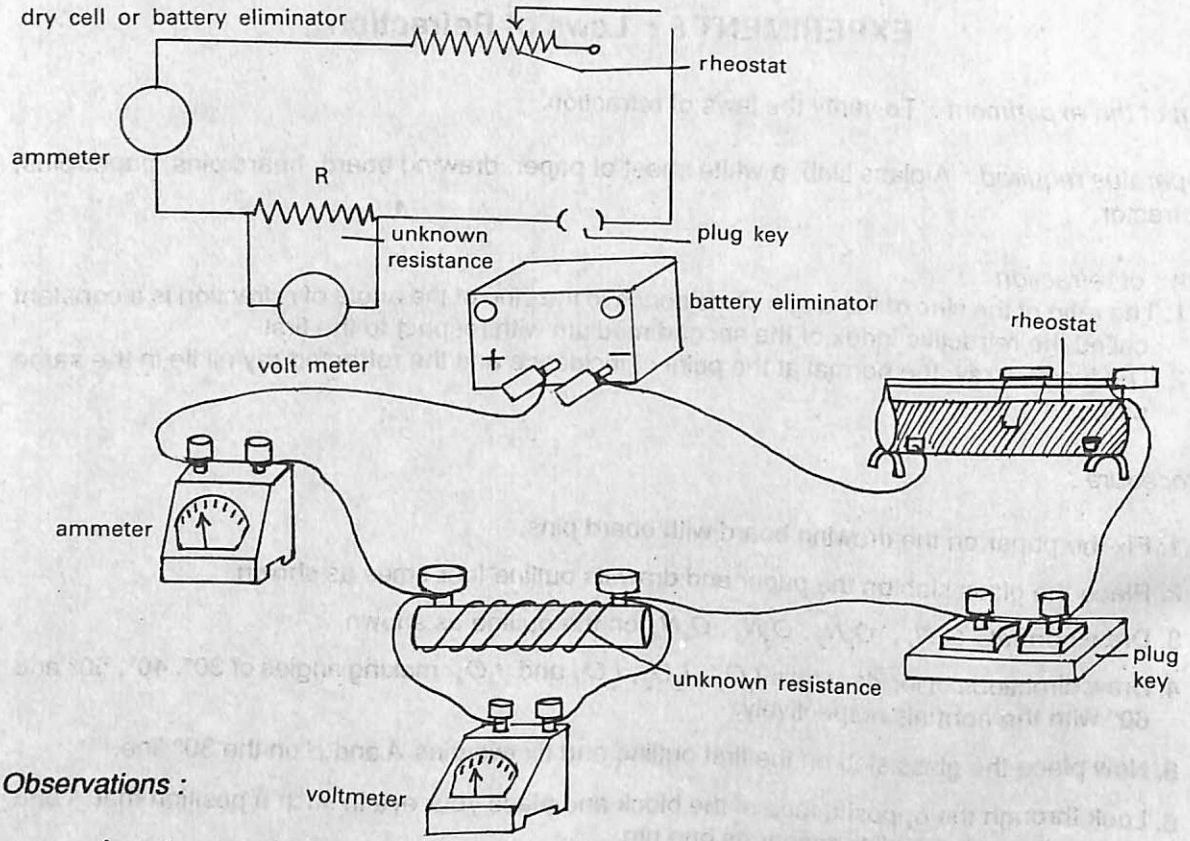
1. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant called the refractive index of the second medium with respect to the first.
2. The incident ray, the normal at the point of incidence and the refracted ray all lie in the same plane.

Procedure :

1. Fix the paper on the drawing board with board pins.
2. Place the glass slab on the paper and draw its outline four times as shown.
3. Draw normals O_1N_1, O_2N_2, O_3N_3, O_4N_4 on the outline as shown.
4. Draw directions of incident rays I_1O_1, I_2O_2, I_3O_3 and I_4O_4 making angles of 30°, 40°, 50° and 60° with the normals respectively.
5. Now place the glass slab on the first outline and fix two pins *A* and *B* on the 30° line.
6. Look through the opposite face of the block and place your eye in such a position that *A* and *B* seen through the slab appear as one pin.
7. Place two pins *E* and *F* so that *A, B, E* and *F* appear to be in a straight line.
8. Draw small circles around the pins and remove them.
9. Join *EF* to meet the outline of the glass slab at *D*.
10. Join O_1D. Measure the anlge of refraction MO_1D.
11. Repeat the above steps for the other three values of angle of incidence and tabulate your readings.
12. Find the values of sin *i* and sin *r* from the log. tables and then find their ratio.

Result : 1. The ratio of sine *i* to sin *r* is a constant as seen from the last column in the tabular form.

2. The incident ray, the normal at the point of incidence and the refracted ray have all been obtained on the plane of the paper – i.e. they lie on the same plane.



Observations :

Least count of ammeter 1 divison = ... amperes.

Least count of voltmeter 1 division = ... volts

Serial No.	*Ammeter Reading I*		*Voltmeter Reading V*		*Resistance R = V/I ohms*
	in divisions	*in amperes*	*in divisions*	*in amperes*	
1					
2					
3					
4					
5					

EXPERIMENT 9 : Measurement of Resistance

Aim of the experiment : To connect up an electrical circuit and determine the unknown value of resistance.

Apparatus required : Dry cell or battery eliminator, ammeter, voltmeter, rheostat, resistance, connecting wires, key.

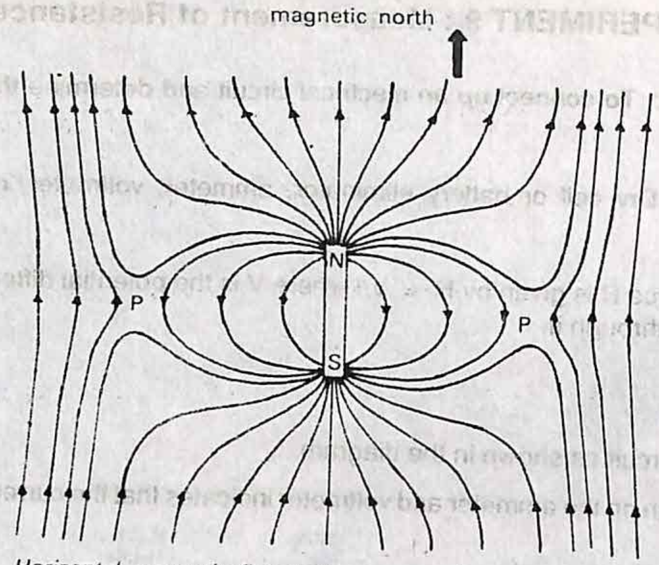
Formula : The resistance R is given by R = V/I where V is the potential difference accross it and I is the current flowing through it.

Procedure :

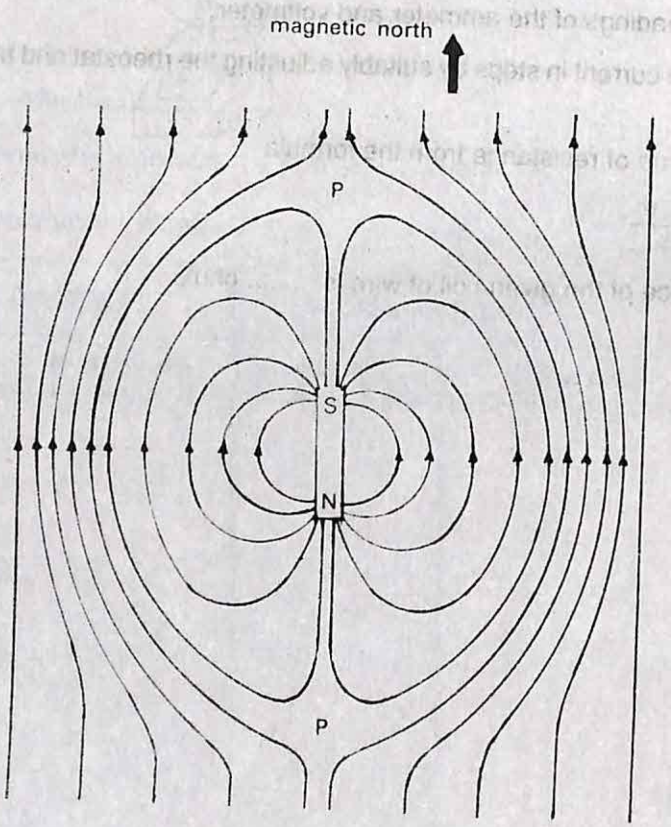
1. Connect up the circuit as shown in the diagram.
2. The (+) and (–) sign on the ammeter and voltmeter indicates that the current should enter at the (+) terminal.
3. Now find the least count of the ammeter and voltmeter.
4. Keeping the rheostat at the maximum value, put the plug in the key.
5. Note down the readings of the ammeter and voltmeter.
6. Now increase the current in steps by suitably adjusting the rheostat and take four more sets of readings.
7. Calculate the value of resistance from the formula

$$R = \frac{V}{I}$$

Result : The resistance of the given coil of wire is .... ohms.



Horizontal magnetic flux pattern near a bar magnet with its axis is the meridian and its N pole pointing north



Horizontal magnetic flux pattern near a bar magnet with its axis in the magnetic meridian and its S pole pointing north

EXPERIMENT 10 AND 11 : Mapping of Magnetic Fields

Aim of the experiment : To plot the magnetic lines of induction of a bar magnet with i) its N–pole point North. ii) S – pole pointing north.

Apparatus required : Drawing board, a sheet of white paper, magnet, compass needle.

Procedure : 1. N-POLE POINTING NORTH

1. Draw a line on the sheet of white paper at the centre and parallel to one of the edges.
2. Place the compass needle on this line and rotate the paper until the compass needle lies exactly over the line.
3. Fix the paper in this position either on a drawing board or on the table, and mark the direction of the north in one corner.
4. Remove the compass box and place the magnet so that its axis lies exactly on the line with its north pole pointing towards the north.
5. Place the compass near the north pole and plot the magnetic line of induction upto the south pole.
6. Bring the compass box back near the N-pole and repeat the procedure.
7. Now repeat the procedure for the other side of the magnet.
8. Look at the diagram for N-pole pointing north and try to obtain as many lines as possible.
9. Locate the null point as shown in diagram. The compass needle will rest in any direction at this point.
10. Measure the distance between the two null points.

2. S-POLE POINTING NORTH

1. Repeat the above procedure with the S-pole of the magnet pointing north.

Result : 1. The magnetic field due to a bar magnet with a) north-pole pointing north and b) S-pole pointing north have been obtained.

2. For N-pole pointing north the distance of neutral point from the centre of the magnet is .... cm = ... m.

For S-pole pointing north the distance of neutral point from the centre is .... cm = ... m.

Test Paper - I

I. Choose the correct answer

1 x 4 = 4

1. All bodies possess

a. centrifugal force. b. momentum. c. inertia. d. uniform motion.

2. A concave mirror has a radius of curvature of 20 cms. An object is placed 15 cm in front of it. The image is

a. inverted and magnified. b. inverted and diminished. c. virtual and erect. d. formed 20 cm from it.

3. If two pieces of different metals have equal thrust upon them when immersed in water then they must have

a. equal weight in air. b. the same density. c. the same volume. d. the same depth beneath the surface.

4. At constant temperature, if the pressure of a gas is doubled, its volume is

a. halved. b. doubled. c. remains the same. d. becomes 1/4 the original volume.

II. State whether true or false.

4 x 1 = 4

1. The momentum of a car and a lorry moving with the same velocity is the same.
2. The distance travelled by the screw when the head is rotated once is called its pitch.
3. One degree on the Kelvin scale is equal to one degree on the centigrade scale.
4. The ratio of the angle of incidence to the angle of refraction is called the refractive index of the medium.

III. Fill in the blanks with suitable words.

4 x 1 = 4

1. The seconds pendulum has a period of ________ seconds.
2. If two cars move in the same direction, with equal velocities, side by side, their relative velocity is ________.
3. The absolute zero correspond to a temperature of ________ °C.
4. A ________ is due to total internal reflection of light travelling from colder layers of air to warmer layers.

IV. Match the following:

3 x 1 = 3

1.	First law of motion	a.	acceleration due to gravity
2.	Second law of motion	b.	action and reaction
3.	Third law of motion	c.	force
		d.	moment of force
		e.	inertia

V. Answer any five questions:

5 x 5 = 25

1. What is meat by the least count and zero error of a screw gauge? How will you determine them?
2. Define moment of a force. State and explain the law of moments.
3. State and explain Pascal's law. What are its applications?
4. At what temperature will the centigrade and fahrenheit thermometers give the same reading.
5. Distinguish between conduction, convection and radiation.
6. A object 5 cm long is placed in front of a convex lens and forms an image of length 25 cm on a screen a distance of 100 cm from the lens. What is its focal length.
7. Write a note on coloured lights and filters.

VI Answer any one question:

1 × 10 = 10

1. Derive the three equations of motion.
2. How will you determine the pressure of a gas using an open-tube manometer.
3. Describe the various methods used for determining the focal length of a concave mirror.

Test Paper II

I. Choose the correct answer.

4 x 1 = 4

1. Two solids of equal volume but different weights are submerged in water.
   a. the loss of weight for both will be same. b. the heavier object will lose more weight. c. they will have the same weight in water. d. they will displace different weights of water.
2. Momentum of a body depends
   a. only on its mass. b. only on its velocity. c. on both mass and velocity. d. on neither mass nor velocity.
3. A person cannot see distant objects clearly. His spectacles should have
   a. convex lenses. b. concave lenses. c. either convex or concave lenses. d. both convex or concave lenses.
4. The minimum resistance that can be obtained with two resistances each of value 2 is
   a. 1/2 ohm. b. 4 ohms. c. 2 ohms. d. 1 ohm.

II. State whether true or false.

4 x 1 = 4

a. In an isothermal expansion of a gas, pressure and temperature remain constant.
b. The effective resistance of 3 ohms and 5 ohms connected in series is 8 ohms.
c. In a uniform magnetic field the lines of force are parallel.
d. The unit of momentum is Nm.

III. Fill in the blanks with suitable words.

4 x 1 = 4

a. The force acting on a body of mass 2 kg to give it an acceleration of 7 ms^{-2} is ________.
b. A concave lens always gives a ________ image.
c. The angle between the direction of the earth's magnetic induction and the horizontal is called the ________
d. The greatest charge resides where the radius of curvature is ________

IV. Match the items in A with suitable items in B.

3 x 1 = 3

A	B
ultraviolet rays	long sight
Infrared rays	heat rays
myopia	convex lens
	short sight
	short wavelength

V. Answer any five questions. 5 x 5 = 25

1. How will you find the density of a liquid using a R.D. bottle?
2. State Newton's second law of motion and derive F = ma.
3. Show that pressure at a point in a liquid P = hdg where h is the depth of the point.
4. Discuss the absolute scale of temperature.
5. Draw a neat diagram and explain the prism-binoculars.
6. Define the magnetic elements at a place with suitable diagrams.
7. Find the effective resistance of 3, 6, and 9 (a) in series (b) in parallel.
8. Write a note on lightning arrestors.

VI. Answer any one of the following: 1 x 10 = 10

1. Describe the screw gauge. How will you use it to determine the thickness of a glass plate?
2. State Archimedes principle. How will you use it to determine the density of a liquid?
3. Describe an experiment to plot the magnetic lines of force for a bar magnet with north pole pointing north. Draw a neat diagram to support your answer.

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